User's Manual

Model 455

DSP Gaussmeter

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Lake Shore certifies that this product has been inspected and tested in accordance with its published specifications and that this product met its published specifications at the time of shipment. The accuracy and calibration of this product at the time of shipment are traceable to the United States National Institute of Standards and Technology (NIST); formerly known as the National Bureau of Standards (NBS).

FIRMWARE LIMITATIONS

Lake Shore has worked to ensure that the Model 455 firmware is as free of errors as possible, and that the results you obtain from the instrument are accurate and reliable. However, as with any computer-based software, the possibility of errors exists.

In any important research, as when using any laboratory equipment, results should be carefully examined and rechecked before final conclusions are drawn. Neither Lake Shore nor anyone else involved in the creation or production of this firmware can pay for loss of time, inconvenience, loss of use of the product, or property damage caused by this product or its failure to work, or any other incidental or consequential damages. Use of our product implies that you understand the Lake Shore license agreement and statement of limited warranty.

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CE

DECLARATION OF CONFORMITY

We: **Lake Shore Cryotronics, Inc.**
575 McCorkle Blvd.
Westerville, OH 43082 USA

hereby declare that the equipment specified conforms to the following Directives and Standards:

Application of Council Directives..... **2006/95/EC** LVD
2004/108/EC EMC

Standards to which Conformity is declared..... **EN-61010-1:2010**
Overvoltage II
Pollution Degree 2
EN 61326-1:2013
Class A
Annex B

Model Number..... 455

Scott Ayer
Scott Ayer 2-18-2014

Director of Quality and Compliance
Position

The Model 455 is considered Waste Electrical and Electronic Equipment (WEEE) Category 9 equipment, therefore falling outside the current scope of the RoHS directive. However, in recognition that RoHS compliance is in the best interest of our customers, employees, and the environment, Lake Shore has designed the Model 455 instrument to eliminate the hazardous substances covered in the RoHS directive. Although the instrument itself does not contain any of these restricted materials, the Hall probes and generators used with it do contain them, which makes the instrument not RoHS compliant.

Electromagnetic Compatibility (EMC) for the Model 455 Gaussmeter

Electromagnetic Compatibility (EMC) of electronic equipment is a growing concern worldwide. Emissions of and immunity to electromagnetic interference is now part of the design and manufacture of most electronics. To qualify for the CE Mark, the Model 455 meets or exceeds the requirements of the European EMC Directive 89/336/EEC as a **CLASS A** product. A Class A product is allowed to radiate more RF than a Class B product and must include the following warning:

WARNING: This is a Class A product. In a domestic environment, this product may cause radio interference in which case the user may be required to take adequate measures.

The instrument was tested under normal operating conditions with a probe and interface cables attached. If the installation and operating instructions in the User's Manual are followed, there should be no degradation in EMC performance.

This instrument is not intended for use in close proximity to RF Transmitters such as two-way radios and cell phones. Exposure to RF interference greater than that found in a typical laboratory environment may disturb the sensitive measurement circuitry of the instrument.

Pay special attention to instrument cabling. Improperly installed cabling may defeat even the best EMC protection. For the best performance from any precision instrument, follow the installation instructions in the User's Manual. In addition, the installer of the Model 455 should consider the following:

- Shield measurement and computer interface cables.
- Leave no unused or unterminated cables attached to the instrument.
- Make cable runs as short and direct as possible. Higher radiated emissions is possible with long cables.
- Do not tightly bundle cables that carry different types of signals.

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CHAPTER 1

INTRODUCTION

1.0 GENERAL

This chapter provides an introduction to the Model 455 DSP Gaussmeter. The Model 455 was designed and manufactured in the United States of America by Lake Shore Cryotronics, Inc. The Model 455 includes the following.

- Field ranges from 35 mG to 350 kG
- DC resolution to 0.02 mG
- Basic DC accuracy of ±0.075%
- DC to 20 kHz AC frequency response
- AC narrow and wide band modes
- Wide range of standard and custom Hall probes available
- Standard Hall probe included

1.1 DESCRIPTION

The Model 455 digital signal processing (DSP) gaussmeter combines the technical advantages of DSP technology with many advanced features at a moderate price. DSP technology creates a solid foundation for accurate, stable, and repeatable field measurements. Advanced features including DC to 20 kHz AC frequency response, peak field detection to 50 µs pulse widths, DC accuracy of 0.075%, and up to 5¾ digits of display resolution make the Model 455 ideal for both industrial and research applications. For added functionality and value, the Model 455 includes a standard Lake Shore Hall probe.

DC Measurement Mode. Static or slowly changing fields are measured in DC mode. In this mode, the Model 455 takes advantage of the internal auto zero function and probe linearity compensation to provide a basic DC accuracy of ±0.075%. Measurement resolution is enhanced by advanced signal processing capability, allowing users the choice of reading rates to 30 readings per second or high resolution to 5¾ digits. Front-end amplification specifically designed to complement DSP data acquisition provides high stability and repeatability. That along with probe temperature compensation provides superior stability ideally suited for demanding DC measurement applications such as field mapping.

455_Front.bmp

Figure 1-1. Model 455 Front Panel

Description (Continued)

RMS Measurement Mode. Periodic AC fields are measured in RMS mode. The Model 455 provides an overall RMS frequency range of 10 Hz to 20 kHz and is equipped with both narrow and wide band frequency modes. While in narrow band mode, frequencies above 1 kHz are filtered out for improved measurement performance. The exclusive DSP algorithms free the Model 455 from the limitations of conventional RMS conversion hardware and provide for an excellent dynamic range, resolution, and frequency response.

Peak Measurement Mode. Pulsed fields are measured in Peak mode, which is a natural extension of the high-speed data acquisition necessary for DSP operation. Fast instrument sample rates permit capture of positive and negative transient fields as narrow as 50 µs pulse widths. The peak reading can be held for an unlimited length of time with no sag. This is ideal for most magnetizers and other fast pulse applications. The Model 455 can also be configured to follow the peak of a periodic waveform for evaluation of crest factor.

The Probe Connection. The Model 455 is only half of the magnetic measurement equation. For the complete solution, Lake Shore offers a full complement of standard and custom Hall effect probes in a variety of sizes and sensitivities. One of ten common standard Hall probes is included with the Model 455. Refer to Section 7.2.3 for a list of available probes, including details on the 1 of 10 Hall probes you can choose to receive with the Model 455.

1.1.1 Measurement Features

The Model 455 offers a variety of features to enhance the usability and convenience of the gaussmeter.

Auto Range: In addition to manual range selection, the instrument automatically chooses an appropriate range for the measured field. Auto range works in DC and AC measurement modes.

Auto Probe Zero: Allows the user to zero all ranges for the selected measurement mode with the push of a key.

Display Units: Field magnitude can be displayed in units of G, T, Oe, and A/m.

Max/Min Hold: The instrument stores the fully processed maximum and minimum DC or RMS field value. This differs from the faster peak capture feature that operates on broadband, unprocessed field reading information.

Relative Reading: Relative feature calculates the difference between a live reading and the relative setpoint to highlight deviation from a known field point. This feature can be used in DC, RMS, or Peak measurement mode.

Instrument Calibration: Lake Shore recommends an annual recalibration schedule for all precision gaussmeters. Recalibrations are always available from the factory, but the Model 455 allows users to field calibrate the instrument if necessary. Recalibration requires a computer interface and precision low resistance standards of known value.

1.1.2 Instrument Probe Features

The Model 455 has the best measurement performance when used along with Lake Shore Hall probes. Firmware-based features work in tandem with the probe's calibration and programming to ensure accurate, repeatable measurements and ease of setup. Many of the features require probe characteristics that are stored in the probe connector's non-volatile memory.

Probe Field Compensation: The Hall effect devices used in gaussmeter probes produce a near linear response in the presence of magnetic field. The small nonlinearities present in each individual device can be measured and subtracted from the field reading. Model 455 probes are calibrated in this way to provide the most accurate DC readings.

Probe Temperature Compensation: Hall effect devices show a slight change in sensitivity and offset with temperature. Probe temperature effects can be measured and subtracted out of field readings. A temperature sensor in the probe tip relays real time temperature to the gaussmeter, enabling compensation. Although temperature effects contribute only a small fraction of the overall probe measurement accuracy, temperature compensation will often improve measurement and control stability.

Probe Temperature Display: The gaussmeter can display the probe's temperature in °C along with a field reading when using a probe that includes a temperature sensor.

Frequency Display: When operating in RMS mode, the gaussmeter can display the frequency of the measured AC field along with a field reading.

Instrument Probe Features (Continued)

Probe Information: The gaussmeter reads the probe information on power up or any time the probe is changed to allow hot swapping of probes. Critical probe information can be viewed on the front panel and read over the computer interface to ensure proper system configuration.

Extension Cables: The complex nature of Hall effect measurements make it necessary to match extension cables to the probe when longer cables are needed. Keeping probes and their extensions from getting mixed up can become a problem when more than one probe is in use. The Model 455 alleviates most of the hassle by allowing users to match probes to extensions in the field. Stored information can be viewed on the front panel and read over the computer interface to ensure proper mating.

Hall Effect Generators (Magnetic Field Sensors): The Model 455 will operate with a discrete Hall effect generator when a suitable probe is not available. Users can program nominal sensitivity and serial number into an optional HMCBL-6 blank connector to provide all gaussmeter functions except field and temperature compensation. If no sensitivity information is available, the Model 455 reverts to resistance measurement.

1.1.3 Display and Interface Features

Display. The Model 455 has a 2-line by 20-character vacuum fluorescent display. During normal operation, the display is used to report field readings and give results of other features such as max/min or relative. The display can also be configured to show probe temperature or frequency. When setting instrument parameters, the display gives the operator meaningful prompts and feedback to simplify operation. The operator can also control display brightness.

Following are three examples of the various display configurations:

The display configured to show the RMS field value and frequency, and the probe temperature.

The display configured to show both the Maximum and Minimum DC field values.

The display configured to simultaneously show the positive and negative Peak readings.

Keypad. The instrument has a 22-position keypad with individual keys assigned to frequently used features. Menus are reserved for less frequently used setup operations. The keypad can be locked out to prevent unintended changes of instrument setup.

Alarm and Relay. High and low alarms are included in the instrument. Alarm actuators include display annunciator, audible beeper, and two relays. The relays can also be controlled manually for other system needs.

Voltage Output 1. The first voltage output gives access to amplified voltage signal directly from the probe. This voltage is corrected for the nominal sensitivity of the probe and provides the widest bandwidth of the three voltage outputs. In wide band AC mode, the signal can be viewed on an oscilloscope to observe the shape of AC fields. In peak mode, the output can be used to view a pulse shape or other characteristic of a momentary signal. Output 1 serves only as a diagnostic tool in DC and narrow band AC modes because modulation of the probe signal prevents a clear view of the field response.

Display and Interface Features (Continued)

Voltage Output 2. The second voltage output provides a voltage proportional to measured field with the benefits of some signal processing. The output is produced by the DSP through a fast D/A converter. The output signal is updated at 40 kHz, giving good response for low to mid frequency fields. Signal quality degrades at high frequency because of the sampling rate. This voltage can be corrected for probe offset and for the nominal sensitivity of the probe.

Voltage Output 3. The third output provides a voltage proportional to measured field with the most signal processing of the three outputs. All probe compensation available to the display readings, including temperature compensation, can be performed on this output. The output is produced by the micro-processor through a 16-bit D/A converter updated at 30 readings per second.

Computer Interface. Two computer interfaces are included with the Model 455: serial (RS-232C) and parallel (IEEE-488). Both allow setup of all instrument parameters and read-back of measured values. The reading rate over the interface is nominally 30 readings per second. LabVIEW™ drivers are provided to instrument users. Consult with Lake Shore for availability.

1.2 SPECIFICATIONS

Does not include probe error, unless otherwise specified.

General Measurement

Input type: Single Hall effect sensor
Probe features: Linearity compensation, temperature compensation, auto probe zero, and hot swap
Measurement features: Autorange, max/min hold, relative mode, and frequency
Connector: 15-pin D-style

DC Measurement

Probe Type Ranges	5¾-digit resolution	4¾-digit resolution	3¾-digit resolution
HST Probe			
350 kG	000.001 kG	000.01 kG	000.1 kG
35 kG	00.0001 kG	00.001 kG	00.01 kG
3.5 kG	0.00001 kG	0.0001 kG	0.001 kG
350 G	000.003 G	000.02 G	000.1 G
35 G	00.0030 G	00.015 G	00.04 G
HSE Probe			
35 kG	00.0001 kG	00.001 kG	00.01 kG
3.5 kG	0.00001 kG	0.0001 kG	0.001 kG
350 G	000.001 G	000.01 G	000.1 G
35 G	00.0003 G	00.002 G	00.01 G
3.5 G	0.00030 G	0.0015 G	0.004 G
UHS Probe			
35 G	00.0001 G	00.001 G	00.01 G
3.5 G	0.00001 G	0.0001 G	0.001 G
350 mG	000.003 mG	000.02 mG	000.1 mG
35 mG	00.0030 mG	00.015 mG	00.04 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for shorted input (Probe effects not included). Value measured as peak-to-peak divided by 6.6.
Display resolution: Indicated by number of digits in above table

	5¾-digit resolution	4¾-digit resolution	3¾-digit resolution
3dB bandwidth	1 Hz	10 Hz	100 Hz
Time constant	1 s	0.1 s	0.01 s
Max reading rate	10 rdg/s	30 rdg/s	30 rdg/s

DC accuracy: ±0.075% of reading ±0.005% of range
DC temperature coefficient: ±0.01% of reading ±0.003% of range per °C

Specifications (Continued)

AC RMS Measurement

Probe Type Ranges	4¾-digit resolution
HST Probe	
350 kG	000.01 kG
35 kG	00.001 kG
3.5 kG	0.0002 kG
350 G	000.02 G
35 G	00.020 G
HSE Probe	
35 kG	00.001 kG
3.5 kG	0.0001 kG
350 G	000.02 G
35 G	00.002 G
3.5 G	0.0020 G
UHS Probe	
35 G	00.001 G
3.5 G	0.0002 G
350 mG	000.02 mG
35 mG	00.020 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for shorted input
Display resolution: Indicated by number of digits in above table
Max reading rate: 30 rdg/s
AC accuracy: ±1% of reading ≥1% of full scale range, 10 Hz to 20 kHz
AC frequency range: 10 Hz to 1 kHz, narrow band mode
135 Hz to 20 kHz, wide band mode

Peak Measurement

Probe Type Ranges	4¾-digit resolution
HST Probe	
350 kG	000.01 kG
35 kG	00.001 kG
3.5 kG	0.0002 kG
350 G	000.02 G
35 G	00.020 G
HSE Probe	
35 kG	00.001 kG
3.5 kG	0.0001 kG
350 G	000.02 G
35 G	00.002 G
3.5 G	0.0020 G
UHS Probe	
35 G	00.001 G
3.5 G	0.0002 G
350 mG	000.02 mG
35 mG	00.020 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for periodic mode and shorted input
Display resolution: Indicated by number of digits in above table
Max reading rate (periodic mode): 30 rdg/s
Peak accuracy: 5 Hz to 20 kHz, ±2% of reading ≥ 1% of full scale range (50 µs or longer pulse width)
Peak frequency range (periodic mode): 50 Hz to 5 kHz
Peak frequency range (pulse mode): 5 Hz to 20 kHz

Temperature Measurement

Temperature range: Probe dependent (typically 0 to 75 °C)
Measurement resolution: 0.01 °C
Temperature display resolution: 0.01 °C
Electronic accuracy: ±0.7 °C

Specifications (Continued)

Front Panel

Display type: 2 line × 20 character, vacuum fluorescent with 9 mm high characters
Display resolution: To ±5¾ digits
Display update rate: 5 rdg/s
Display units: gauss (G), tesla (T), oersted (Oe), and ampere per meter (A/m)
Units multipliers: μ, m, k, M

Display annunciators:	DC	DC measurement mode
	RMS	AC RMS measurement mode
	PK	Peak measurement mode
	MX	Max hold value
	MN	Min hold value
	SP	Relative setpoint value
LED annunciators:	Relative	Relative reading mode
	Alarm	Alarm active
	Remote	Remote IEEE-488 operation

Keypad: 22 full-travel keys
Front panel features: Display prompts, front panel lock-out, and brightness control

Interfaces

RS-232C:
Baud: 9600, 19200, 38400, and 57600
Update rate: 30 rdg/s
Software support: LabVIEW™ driver
Connector: 9-pin D-style, DTE configuration

IEEE-488.2:
Capabilities: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, and E1
Update rate: 30 rdg/s
Software Support: LabVIEW™ driver
Alarm:
Settings: High/low setpoint, inside/outside, and audible
Actuators: LED annunciator, beeper, and relays

Relays:
Number: 2
Contacts: Normally open (NO), normally closed (NC), and common (C)
Contact rating: 30 VDC at 2 A
Operation: Follows alarm or operated manually
Connector: Shared 25-pin I/O connector

Voltage Output 1:
Configuration: Real-time analog voltage output of wide band AC signal
Range: ±3.5 V
Scale: ±3.5 V = ± full scale on selected range
Frequency response: 10 Hz to 20 kHz (wide band AC)
Accuracy: Probe dependent
Noise: ±1.0 mV RMS
Minimum load resistance: 1 kΩ (short-circuit protected)
Connector: Shared 25-pin I/O connector

Voltage Output 2:
Configuration: Voltage output of field value, generated by DAC
Range: ±5 V
Scale: ±3.5 V = ± full scale on selected range
Resolution: 16-bit, 0.15 mV
Update rate: 40,000 updates/s
Accuracy: ±10 mV
Noise: ±0.3 mV RMS
Minimum load resistance: 1 kΩ (short-circuit protected)
Connector: Shared 25-pin I/O connector

Specifications (Continued)

Voltage Output 3:
Configuration: Voltage output of compensated DC or RMS field value, generated by DAC
Range: ±10 V
Scale: User specified (defaults same as voltage output 2)
Resolution: 16-bit, 0.3 mV
Update rate: 30 updates/s
Accuracy: ±2.5 mV
Noise: ±0.3 mV RMS
Minimum load resistance: 1 kΩ (short-circuit protected)
Connector: Shared 25-pin I/O connector

General

Ambient temperature: 15 to 35 °C at rated accuracy, 5 to 40 °C with reduced accuracy
Power requirement: 100, 120, 220, 240 VAC (+6%, –10%), 50 Hz or 60 Hz, 20 VA
Size: 216 mm W × 89 mm H × 318 mm D (8.5 in × 3.5 in × 12.5 in), half rack
Weight: 3 kg (6.6 lb)
Approval: CE mark

Probes and Extensions:
Probe compatibility: Full line of standard probes and custom probes (Not compatible with Model 450/421 probes)
Hall sensor compatibility: Front panel programmable sensitivity and serial number for user supplied Hall sensor
Extension cable compatibility: Calibrated or uncalibrated probe extension cables with an EEPROM are available from 10 ft to 100 ft
Lake Shore calibrated extension cables maintain the same accuracy as the Model 455 probe
The uncalibrated version involves the operator loading the matching probe data file into the cable PROM directly from the Model 455 front panel. Additional errors caused by the uncalibrated extension cables are ±0.02% of field reading error and 1 °C temperature reading error

Ordering Information

Part Number	Description
455	Model 455 Gaussmeter
Specify Line Power Option:	
VAC-100	100 VAC configured, includes U.S. power cord
VAC-120	120 VAC configured, includes U.S. power cord
VAC-220	220 VAC configured, includes Universal Europe power cord
VAC-240	240 VAC configured, includes Universal Europe power cord
VAC-120-ALL	120 VAC configured, includes U.S. and Universal Europe power cords and all fuses
Accessories Included:	
G-106-253	I/O mating connector
G-106-264	I/O mating connector shell
4060	Zero gauss chamber
MAN-455	Model 455 Gaussmeter user manual
Accessories Available:	
4005	1 m (3 ft) long IEEE-488 (GPIB) computer interface cable assembly – includes extender required for simultaneous use of IEEE cable and auxiliary I/O connector
4065	Large zero gauss chamber for Gamma probe
RM-½	Rack mount kit for one ½ rack gaussmeter in 483 mm (19 in.) rack
RM-2	Rack mount kit for two ½ rack gaussmeter in 483 mm (19 in.) rack
HMCBL-6	User programmable cable with EEPROM (6 ft)
HMCBL-20	User programmable cable with EEPROM (20 ft)
HMPEC-10	Probe extension cable with EEPROM (10 ft), calibrated
HMPEC-10-U	Probe extension cable with EEPROM (10 ft), uncalibrated
HMPEC-25	Probe extension cable with EEPROM (25 ft), calibrated
HMPEC-25-U	Probe extension cable with EEPROM (25 ft), uncalibrated
HMPEC-50	Probe extension cable with EEPROM (50 ft), calibrated
HMPEC-50-U	Probe extension cable with EEPROM (50 ft), uncalibrated
HMPEC-100	Probe extension cable with EEPROM (100 ft), calibrated
HMPEC-100-U	Probe extension cable with EEPROM (100 ft), uncalibrated
Calibration Service:	
CAL-N7-DATA	New instrument calibration for Model 455/475 with certificate and data
CAL-455	Instrument recalibration with certificate
CAL-455DATA	Instrument recalibration with certificate and data

Specifications are subject to change without notice.

1.3 SAFETY SUMMARY

Observe these general safety precautions during all phases of instrument operation, service, and repair. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended instrument use. Lake Shore Cryotronics, Inc. assumes no liability for Customer failure to comply with these requirements.

The Model 455 protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument. Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area.

- Indoor use.
- Altitude to 2000 meters.
- Temperature for safe operation: 5 °C to 40 °C.
- Maximum relative humidity: 80% for temperature up to 31 °C decreasing linearly to 50% at 40 °C.
- Power supply voltage fluctuations not to exceed ±10% of the nominal voltage.
- Overvoltage category II.
- Pollution degree 2.

Ground the Instrument

To minimize shock hazard, the instrument is equipped with a 3-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet or use a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

Ventilation

The instrument has ventilation holes in its side covers. Do not block these holes when the instrument is operating.

Do Not Operate In An Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

Keep Away From Live Circuits

Operating personnel must not remove instrument covers. Refer component replacement and internal adjustments to qualified maintenance personnel. Do not replace components with power cable connected. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Substitute Parts Or Modify Instrument

Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an authorized Lake Shore Cryotronics representative for service and repair to ensure that safety features are maintained.

Cleaning

Do not submerge instrument. Clean only with a damp cloth and mild detergent. Exterior only.

1.4 SAFETY SYMBOLS

Direct current (power line).

Alternating current (power line).

Alternating or direct current (power line).

Three-phase alternating current (power line).

Earth (ground) terminal.

Protective conductor terminal.

Frame or chassis terminal.

On (supply).

Off (supply).

Equipment protected throughout by double insulation or reinforced insulation (equivalent to Class II of IEC 536 - see Annex H).

Caution: High voltages; danger of electric shock. Background color: Yellow; Symbol and outline: Black.

Caution or Warning - See instrument documentation. Background color: Yellow; Symbol and outline: Black.

Fuse.

CHAPTER 2
BACKGROUND

2.0 GENERAL

This chapter provides background information related to the Model 455 Gaussmeter. It is intended to give the user insight into the benefits and limitations of the instrument and help apply the features of the Model 455 to a variety of experimental challenges. It covers basic DSP concepts and how they are applied to the operation of the Model 455, flux density and Hall measurement, and probe operation. For information on how to install the Model 455 please refer to Chapter 3. Instrument operation information is contained in Chapter 4 and Chapter 5.

2.1 MODEL 455 THEORY OF OPERATION

2.1.1 Sampled Data Systems

Humans rely on analog signals to interact with their environment: individual wavelengths of light are converted to colors, pressure waves are interpreted as sound, and the vibration of vocal cords creates speech. In the fields of science and engineering, a variety of sensors are used to convert analog signals of interest into some electrical property, usually voltage, so that they can be measured or used as an input to a system. Analog-to-digital converters (ADC) and digital-to-analog converters (DAC) allow computers in the digital domain to interact with these analog signals.

Digital signals are different from continuous analog signals in the fact that they are sampled in time and quantized in amplitude. Both of these properties limit the ability of the digital representation to match the original analog signal. An ADC will sample a signal at fixed intervals of time. Quantization results from the fact that an ADC has a limited amount of resolution. When both the sampling frequency and resolution are properly chosen however, the digital signal is an accurate representation of the original analog signal. The sampling frequency of the Model 455 allows an accurate RMS measurement to be made on signals of up to 20 kHz. The sampling and filtering in the Model 455 can allow realizable resolutions of 20 bits, which is in the noise floor of the instrument.

2.1.2 Digital Signal Processing

Digital Signal Processing (DSP) is the science of manipulating digital data through the use of mathematics. The variety of processing that can be done is almost endless, from simulating an analog filter, to enhancing a visual image, to encrypting sensitive information. Digital Signal Processing is being used in more and more products due to its accuracy, flexibility, and reliability.

The Model 455 gaussmeter is an ideal product that can benefit from DSP technology. The Model 455 offers the user a choice of AC wide band or narrow band modes. The components that are used in analog signal processing can have different values from component to component and are temperature dependent. Using Digital Signal Processing gives better measurement repeatability and increases the temperature stability of the instrument.

2.1.3 Limitations of Sampled Data Systems

Sampled data systems do have their limitations, but if they are understood, they can be dealt with easily. The limitations of sampled data systems come from the fact that a continuous analog signal is being sampled and digitized. This inherently limits the frequency of the signal that can be read as well as the resolution at which it can be read. Typically, the resolution is high enough and enough averaging is done that it does not present a problem. The frequency limitation can cause unique problems. There are notches in the frequency response as the input signal approaches one-half the sampling rate and its harmonics. As the measured signal approaches these harmonic frequencies, the reading will fall off due to the null in the filter.

The rate at which an analog signal must be sampled depends on the frequency content of the signal. A signal is said to be properly sampled if the original signal can be exactly reconstructed from the digital information. It turns out that a signal can only be properly reconstructed if the signal does not contain frequencies above one-half of the sampling rate. This is referred to as the Nyquist frequency. In the case of the Model 455, the ADC is sampled at 40 kHz in wide band AC mode. In this mode, the highest frequency signal that can be accurately represented out of Analog Output 2 is 20 kHz due to the limit of the Nyquist frequency. In this case, Analog Output 1 should be used to monitor the signal.

Limitations of Sampled Data Systems (Continued)

It should be noted that although the Nyquist frequency will limit the signal that can be accurately reconstructed, it doesn't affect the RMS reading of the signal. The energy content of the signal above the Nyquist frequency will be aliased to lower frequencies where it will be included in the RMS calculation.

2.1.4 Model 455 System Overview

The Model 455 Gaussmeter is a highly configurable device with many built-in features. To better illustrate the capabilities of the DSP Gaussmeter., refer to the Model 455 system block diagram, Figure 2-1.

The Model 455 uses a 100 mA, 5 kHz square wave excitation to drive the Hall sensor in DC mode and narrow band AC mode. In wide band AC mode, it uses a 100 mA, DC excitation to drive the sensor. The Hall voltage produced by the sensor is fed back into the instrument and sent through a programmable gain stage. The signal is then AC coupled into the A/D where it is read at up to 50 kHz. Those signals are then sent to the DSP where the signal processing is done and the readings are filtered. The data is then transferred to the microprocessor where the readings can be sent to the display or out to the computer interface.

The Model 455 has three different analog outputs, each one providing different information. Analog Output 1 is a pure analog output being taken just before the A/D and is corrected for nominal probe sensitivity. In wide-band AC mode, this represents the actual signal being generated by the Hall sensor. It is not as useful in narrow-band AC and DC modes where the output is going to contain the 5 kHz excitation frequency.

Analog Output 2 is generated from a high speed D/A converter controlled by the DSP. This output is generated from the data after the product detector and is a representation of the actual field being measured. A measured DC field will appear as a DC signal and an AC field will appear as an AC signal. Analog Output 2 is corrected for nominal probe sensitivity and probe zero offset.

Analog Output 3 is generated from a D/A converter controlled by the microprocessor. This output has many different modes of operation including manual output and to output a voltage that is proportional to the field being read, including probe zero offset, field compensation, and temperature compensation. If the instrument is set up in AC mode, then the output is a DC voltage proportional to the RMS value of the field.

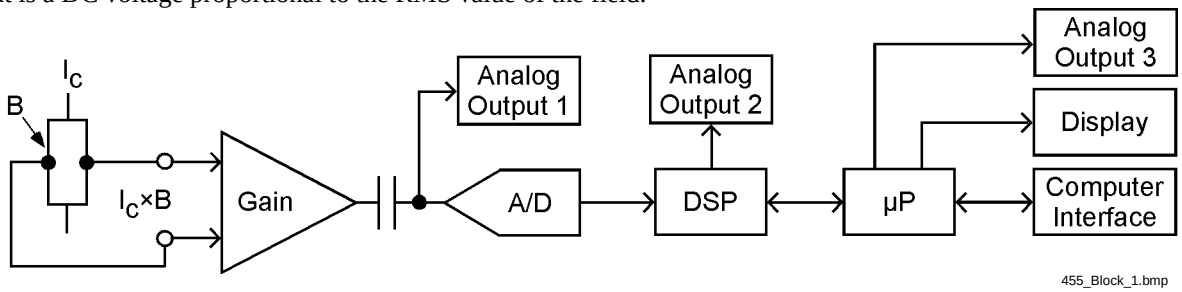


Figure 2-1. Model 455 System Block Diagram

2.1.5 DC Measurement

The DC mode should be used to measure static or slowly changing fields. When in DC mode, the instrument uses a 100 mA, 5kHz, square wave excitation current. The voltage that is generated by the Hall device is read by the A/D at 50 kHz and is then digitally processed using a product detector and a low-pass filter to create a DC reading. The readings are then averaged using a configurable averaging filter that can give a high-speed reading or a low-speed, high-resolution reading. Refer to Section 4.6.2 for information on how to set the DC filter. Analog Output 2 can be used to output a digitally derived, DC representation of the field being measured over the DC frequency band.

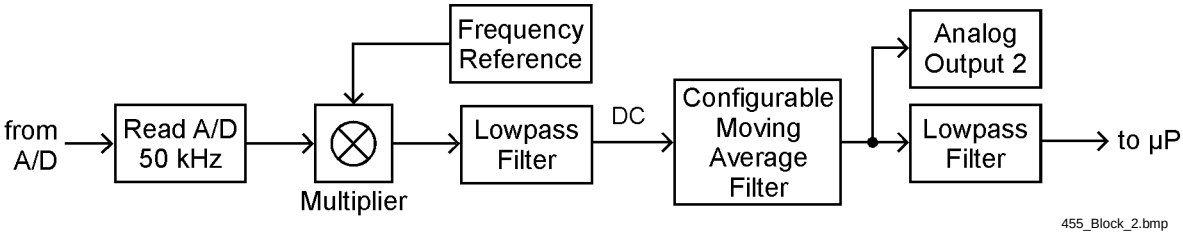


Figure 2-2. DC Measurement Block Diagram

2.1.6 RMS Measurement

The Model 455 offers two different modes of AC measurement, narrow-band and wide-band. In narrow-band AC measurement, the instrument uses a 100 mA, 5 kHz, square wave excitation current. This type of excitation provides the benefit of noise cancellation characteristics of the product detector but limits the maximum frequency to approximately 1 kHz. The voltage that is generated by the Hall device is read by the A/D at 50 kHz and is then digitally processed using a product detector and a low-pass filter to create a broadband AC reading. The readings are then passed through an RMS conversion routine. Refer to Section 4.7.2 for information on how to set the AC measurement band. Analog Output 2 can be used to output a digitally derived, AC representation of the field being measured.

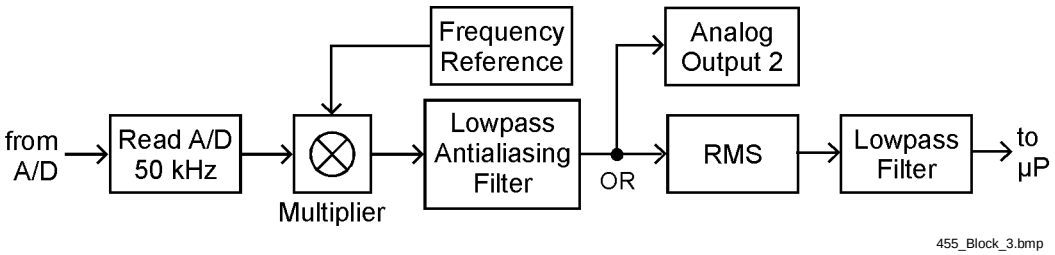


Figure 2-3. RMS Narrow Band AC Block Diagram

In wide-band AC measurement, the instrument uses a 100 mA, DC excitation current. This type of excitation provides the greatest frequency range for RMS measurements, up to 20 kHz. The voltage that is generated by the Hall device is read by the A/D at 40 kHz. The readings are then passed through a RMS conversion routine. Refer to Section 4.7.2 for information on how to set the AC measurement band. Analog Output 1 can be used to output a real time, AC representation of the field being measured. Analog Output 2 can also be used to output a digitally derived, AC representation of the field, for measured fields up to 10 kHz. Measured fields up to 20 kHz may be represented with the addition of external filters to the analog output.

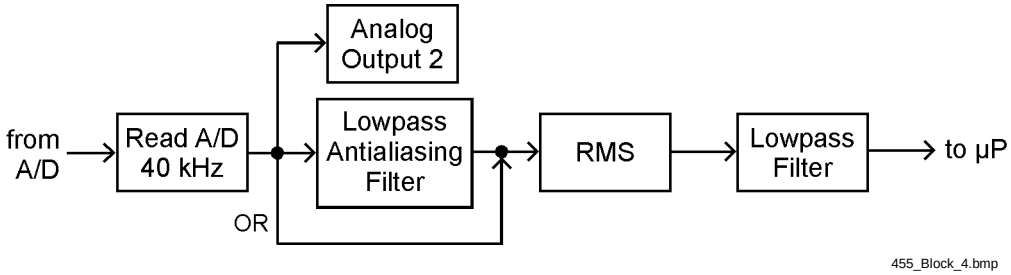


Figure 2-4. RMS Wide Band AC Block Diagram

2.1.7 Peak Measurement

The Model 455 is capable of measuring the peak amplitudes of signals, either peak pulses or periodic pulses. In peak mode the instrument uses a 100 mA, DC excitation current. The voltage that is generated by the Hall device is read by the A/D at 40 kHz. The readings are then passed through a peak detector that will capture and hold a maximum peak pulse value or calculate the value of periodic peaks. Refer to Section 4.8.2 for information on how to setup the peak mode. Analog Output 1 can be used to output a real time representation of the field being measured. Analog Output 2 can also be used to output a digitally derived representation of periodic fields being measured for signals up to 10 kHz. Measured fields up to 20 kHz may be represented with the addition of external filters to the analog output. Analog Output 2 should not be used in pulse mode since it is not fast enough to accurately re-create quick pulses.

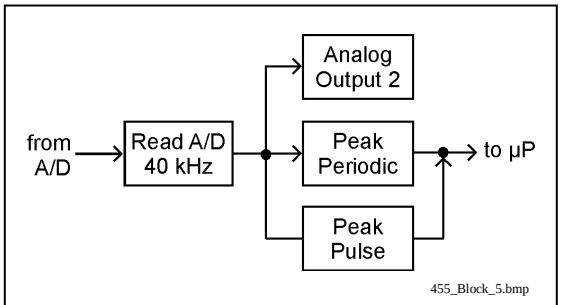


Figure 2-5. Peak Measurement Block Diagram

2.2 FLUX DENSITY OVERVIEW

2.2.1 What is Flux Density?

A magnetic field can be envisioned as consisting of flux lines (**ϕ**). A unit of flux is called a line. In the cgs system, one line of flux equals one maxwell (Mx). In the SI system, the flux unit is the weber (Wb), where:

$$1 Wb = 10^8 Mx = 10^8 lines.$$

Flux density is the number of flux lines passing perpendicular through a plane of unit area (**A**). The symbol for flux density is **B** where **B = ϕ/A**. The cgs system measures flux density in gauss (**G**) where **1 G = 1 Mx/cm^2**. The SI system measures flux density in tesla (**T**) where **1 T = 1 Wb/m^2**.

Flux density is important when magnet systems concentrate flux lines into a specific area like the pole pieces in an electromagnet. Forces generated on current carrying wires like those in a motor armature are proportional to flux density. Saturation of magnetic core material is also a function of flux density.

2.2.2 How Flux Density (B) Differs from Magnetic Field Strength (H)

Flux density is often confused with magnetic field strength. Magnetic field strength is a measure of the force producing flux lines. The symbol for magnetic field strength is **H**. In the cgs system, it is measured in oersteds (**Oe**). In the SI system, it is measured in amperes per meter (**A/m**):

$$1 Oe = 79.58 A/m.$$

Flux density and magnetic field strength are related by the permeability (**μ**) of the magnetic medium. **B = μH**. Permeability is a measure of how well a material makes a path for flux lines.

The confusion of flux density and magnetic field strength is also related to permeability. In the cgs system, the permeability of air (of vacuum) is 1. Therefore, **1 G = 1 Oe** or **B = H** in air. Many people incorrectly assume therefore that in the cgs system, **B = H** at all times. Adding to the confusion, in the SI system permeability of air is not 1, so **B** is not equal to **H** even in air.

2.3 HALL MEASUREMENT

The Hall effect was discovered by E. H. Hall in 1879. For nearly 70 years it remained a laboratory curiosity. Finally, development of semiconductors brought Hall generators into the realm of the practical.

A Hall generator is a solid state sensor that provides an output voltage proportional to magnetic flux density. As implied by its name, this device relies on the Hall effect. The Hall effect is the development of a voltage across a sheet of conductor when current is flowing and the conductor is placed in a magnetic field. See Figure 2-6.

Electrons (the majority carrier most often used in practice) "drift" in the conductor when under the influence of an external driving electric field. When exposed to a magnetic field, these moving charged particles experience a force perpendicular to both the velocity and magnetic field vectors. This force causes the charging of the edges of the conductor, one side positive with respect to the other. This edge charging sets up an electric field which exerts a force on the moving electrons equal and opposite to that caused by the magnetic-field-related Lorentz force. The voltage potential across the width of the conductor is called the Hall voltage. This Hall voltage can be utilized in practice by attaching two electrical contacts to the sides of the conductor.

The Hall voltage can be given by the expression:

$$V_H = \gamma_B B \sin \theta$$

where: V_H = Hall voltage (mV)
γ_B = Magnetic sensitivity (mV/kG) (at a fixed current)
B = Magnetic field flux density (kilogauss)
θ = Angle between magnetic flux vector and the plane of Hall generator.

As can be seen from the formula, above, the Hall voltage varies with the angle of the sensed magnetic field, reaching a maximum when the field is perpendicular to the plane of the Hall generator.

2.3.1 Active Area

The Hall generator assembly contains the sheet of semiconductor material to which the four contacts are made. This entity is normally called a "Hall plate." The Hall plate is, in its simplest form, a rectangular shape of fixed length, width and thickness. Due to the shorting effect of the current supply contacts, most of the sensitivity to magnetic fields is contained in an area approximated by a circle, centered in the Hall plate, whose diameter is equal to the plate width. Thus, when the active area is given, the circle as described above is the common estimation.

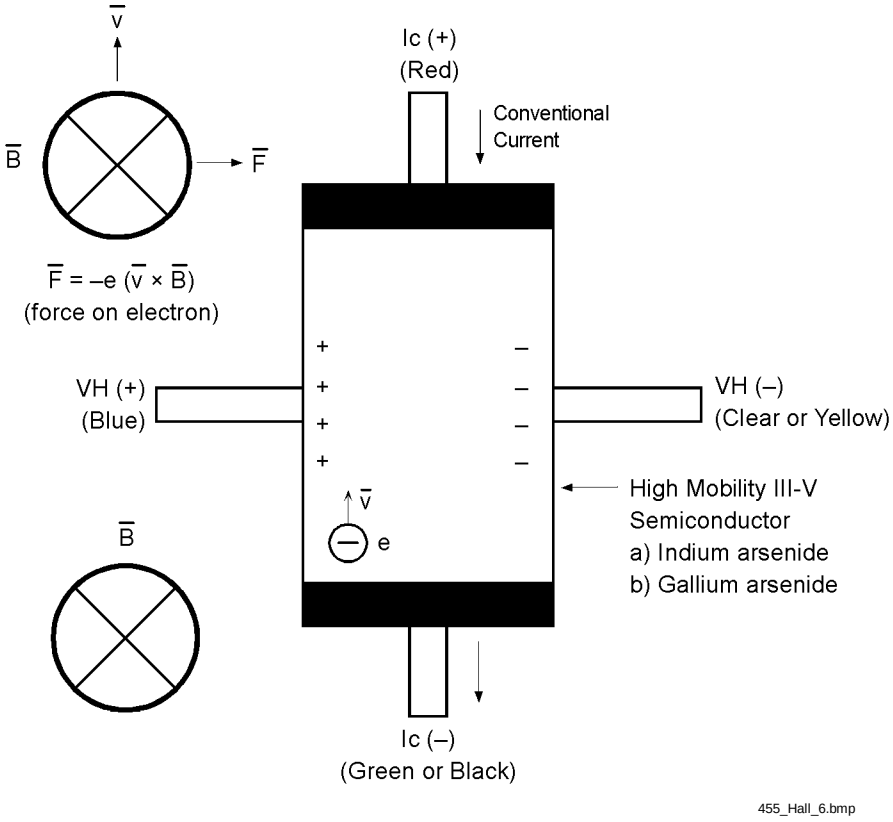


Figure 2-6. Hall Generator Theory

2.3.2 Polarity

If the control current enters the red lead (with $+I_C$ connected to the positive terminal of the current supply), and the magnetic field direction B is as shown in Figure 2-6, a positive Hall voltage will be generated at the $+V_H$ lead. Reversing either the current or the magnetic field will reverse the output voltage.

2.3.3 Orientation

Hall generators come in two main configurations, axial and transverse. Transverse devices are generally thin and rectangular in shape. They are applied successfully in magnetic circuit gaps, surface measurements and general open field measurements. Axial sensors are mostly cylindrical in shape. Their applications include ring magnet center bore measurements, solenoids, surface field detection and general field sensing. Figure 2-7 shows these two orientations.

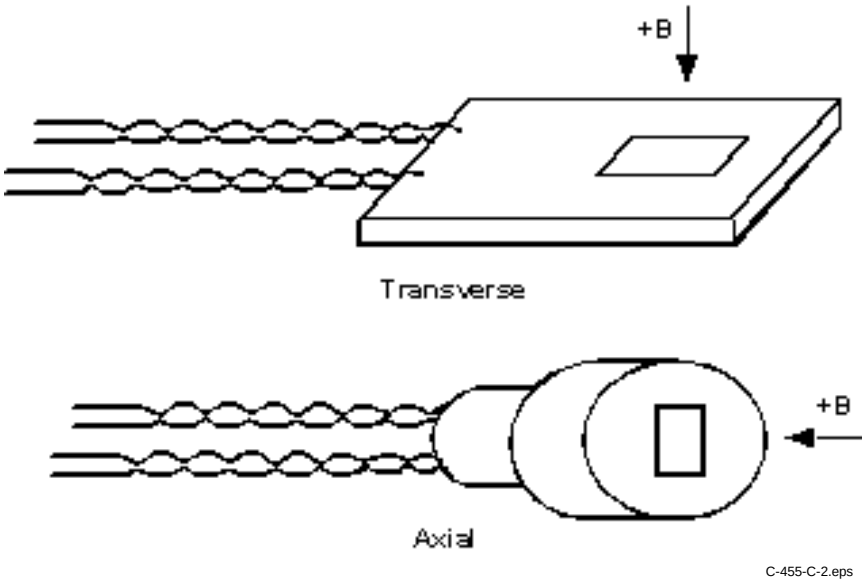


Figure 2-7. Axial and Transverse Configurations

CHAPTER 3

INSTALLATION

3.0 GENERAL

This chapter provides general installation instructions for the Model 455 gaussmeter. Please read this entire chapter before installing the instrument and powering it on to ensure the best possible performance and maintain operator safety. For instrument operating instructions refer to Chapter 4 and Chapter 5. For computer interface installation and operation refer to Chapter 6.

3.1 INSPECTION AND UNPACKING

Inspect shipping containers for external damage before opening them. Photograph any container that has significant damage before opening it. If there is visible damage to the contents of the container contact the shipping company and Lake Shore immediately, preferably within 5 days of receipt of goods. Keep all damaged shipping materials and contents until instructed to either return or discard them.

Open the shipping container and keep the container and shipping materials until all contents have been accounted for. Check off each item on the packing list as it is unpacked. Instruments themselves may be shipped as several parts. The items included with the Model 455 are listed below. Contact Lake Shore immediately if there is a shortage of parts or accessories. Lake Shore is not responsible for any missing items if not notified within 60 days of shipment.

Inspect all items for both visible and hidden damage that occurred during shipment. If damage is found, contact Lake Shore immediately for instructions on how to file a proper insurance claim. Lake Shore products are insured against damage during shipment but a timely claim must be filed before Lake Shore will take further action. Procedures vary slightly with shipping companies. Keep all shipping materials and damaged contents until instructed to either return or discard them.

If the instrument must be returned for recalibration, replacement or repair, a return authorization (RA) number must be obtained from a factory representative before it is returned. The Lake Shore RA procedure is given in Section 8.2.

Probes are shipped in cardboard containers and are often included in the instrument shipping carton. Please retain the probe container for probe storage. This will help protect the delicate probes from being damaged.

Items Included with the Model 455 Gaussmeter

- 1 Model 455 Instrument
- 1 Model 455 User's Manual
- 1 I/O Mating Connector
- 1 Zero Gauss Chamber
- 1 Line Power Cord
- 1 Line Power Cord for Alternative Voltage *
- 1 Fuse Pair for Alternative Voltage *

* Included only when purchased with VAC-120-ALL Power Option.

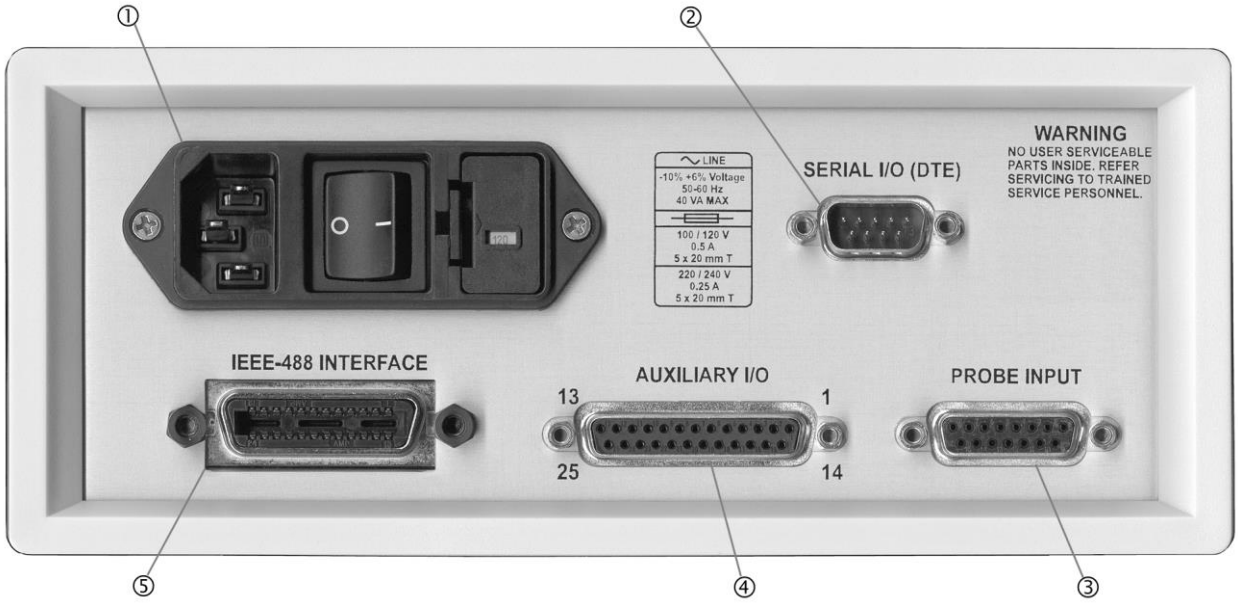
3.2 REAR PANEL DEFINITION

This paragraph defines the rear panel of the Model 455. See Figure 3-1. Readers are referred to paragraphs that contain installation instructions and connector pin-outs for each feature. A summary of connector pin-outs is provided in Section 8.10.

CAUTION: Verify that the AC line voltage indicator in the fuse drawer window shows the appropriate AC line voltage before turning the instrument on.

CAUTION: Make rear panel connections with the instrument power off.

①	**Line Input Assembly**	Includes the IEC 320-C14 line cord receptacle, instrument power switch, and line voltage selector with line voltage indicator and line fuse holder. Refer to Section 3.3.
②	**SERIAL I/O (DTE)**	9 pin D-sub plug wired in DTE configuration for use with RS-232C serial computer interface. Refer to Section 6.2 and see Figure 8-6.
③	**PROBE INPUT**	15 pin D-sub socket for probes or Hall generator cables. For best results, secure the connector to the rear panel using the two thumbscrews. Refer to Section 3.4 for additional probe considerations.
④	**AUXILIARY I/O**	25 pin D-sub plug that provides access to the analog outputs, hardware triggers, and relays. Refer to Section 3.6.
⑤	**IEEE-488 INTERFACE**	IEEE-488 compliant interface connector for use with IEEE-488 parallel computer interface. Refer to Section 6.1 and see Figure 8-7.



455_Rear.bmp

Figure 3-1. Model 455 Rear Panel

3.3 LINE INPUT ASSEMBLY

This section describes how to properly connect the Model 455 to line power. Please follow these instructions carefully to ensure proper operation of the instrument and the safety of operators.

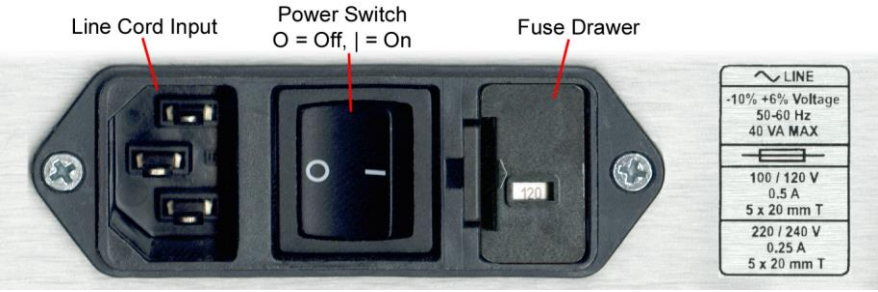


Figure 3-2. Line Input Assembly

3.3.1 Line Voltage

The Model 455 has four different AC line voltages configurations so that it can be operated from line power anywhere in the world. The nominal voltage and voltage range of each configuration is shown below. (The recommended setting for 230 V operation is 240 V.)

Nominal	Minimum	Maximum
100 V	90 V	106 V
120 V	108 V	127 V
220 V	198 V	233 V
240 V	216 V	254 V

Verify that the AC line voltage indicator in the fuse drawer window shows the appropriate AC line voltage before turning the instrument on. The instrument may be damaged if it is turned on with the wrong voltage selected. Instructions for changing the line voltage configuration are given in Section 8.4.

3.3.2 Line Fuse and Fuse Holder

The line fuse is an important safety feature of the Model 455. If a fuse ever fails, it is important to replace it with the value and type indicated on the rear panel for the line voltage setting. The letter T on the fuse rating indicates that the instrument requires a time-delay or slow-blow fuse. Fuse values should be verified any time line voltage configuration is changed. Instructions for changing and verifying a line fuse are given in Section 8.5.

3.3.3 Power Cord

The Model 455 includes a 3-conductor power cord that mates with the IEC 320-C14 line cord receptacle. Line voltage is present on the two outside conductors and the center conductor is a safety ground. The safety ground attaches to the instrument chassis and protects the user in case of a component failure. A CE approved power cord is included with instruments shipped to Europe; a domestic power cord is included with all other instruments (unless otherwise specified when ordered). Always plug the power cord into a properly grounded receptacle to ensure safe operation of the instrument.

3.3.4 Power Switch

The power switch is part of the line input assembly on the rear panel of the Model 455 and turns line power to the instrument On and Off. When the circle is depressed, power is Off. When the line is depressed, power is On.

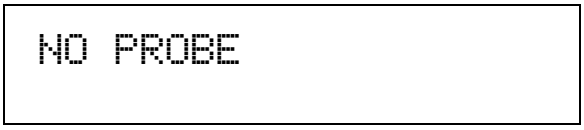
3.4 PROBE INPUT CONNECTION

WARNING: Probes used with the gaussmeter have conductive parts. Never probe near exposed live voltage. Personal injury and damage to the instrument may result.

The Lake Shore probe plugs into the 15 pin D-sub connector on the rear panel. Align the probe connector with the rear panel connector and push straight in to avoid bending the pins. For best results, secure the connector to the rear panel using the two thumbscrews. A tight connector keeps the cable secure and prevents interference. Refer to Section 3.5 for additional probe considerations.

An Electrically Erasable Programmable Read Only Memory (EEPROM) is included in each probe. The EEPROM stores specific information that the gaussmeter requires for operation. The information includes serial number, probe sensitivity, and field compensation data. When a new probe is connected, the instrument reads parameters from probe memory and the probe is ready to use. A new probe can be connected at any time even while the instrument is turned on. No parameters need to be entered into the Model 455 for a Lake Shore probe. However, the Zero Probe function should be performed the first time a probe is used with the instrument and periodically during use.

If the instrument is powered up with no probe attached, the following message is displayed.



3.5 PROBE HANDLING AND OPERATION

To avoid damage and for best results during use, the probes have a number of handling and accuracy requirements that must be observed.

3.5.1 Probe Handling

Although every attempt has been made to make the probes as sturdy as possible, they are still fragile. This is especially true for the exposed sensor tip of some transverse probes. Care should be taken during measurements that no pressure is placed on the tip of the probe. The probe should only be held in place by securing at the handle. The probe stem should never have force applied. Any strain on the sensor may alter the probe calibration, and excessive force may destroy the Hall generator.

CAUTION: Care must be exercised when handling the probe. The tip of the probe is very fragile. Stressing the Hall sensor can alter its calibration. Any excess force can easily break the sensor. Broken sensors are not repairable.

Avoid repeated flexing of the stem of a flexible probe. As a rule, the stem should not be bent more than 45° from the base. See Figure 3-3. Force should never be applied to the tip of the probe. On all probes, do not pinch or allow cables to be struck by any heavy or sharp objects. Although damaged or severed cables should be returned to Lake Shore for repair, please understand that probes are not always repairable.

When probes are installed on the gaussmeter but not in use, the protective tubes provided with many probes should be placed over the probe handle and stem in order to protect the tip. When the gaussmeter is not in use, the probes should be stored separately in some type of rigid container. The cardboard and foam container that Lake Shore probes are shipped in may be retained for probe storage. For further details on available accessories and probes, refer to Chapter 7.

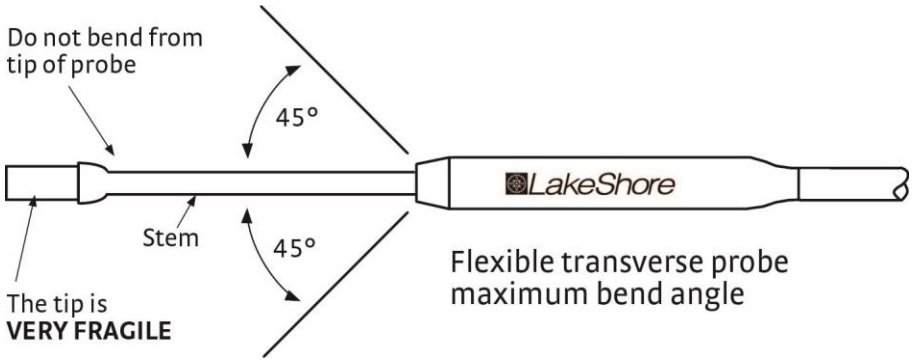


Figure 3-3. Maximum Flexible Probe Bend Radius

3.5.2 Probe Operation

In the DC mode of operation, the orientation of the probe affects the polarity reading of the gaussmeter. On a transverse probe, the Lake Shore name printed on the handle indicates the side for positive (+) flux entry. On an axial probe, positive (+) flux entry is always from the front of the probe. See Figure 3-4.

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

If the exact direction of the magnetic field is unknown, the proper magnitude is determined by turning on **Max Hold** and slowly adjusting the probe. As the probe turns and the measured field rises and falls, its maximum value is held on the display. Make note of the probe orientation at the maximum reading to identify the field orientation.

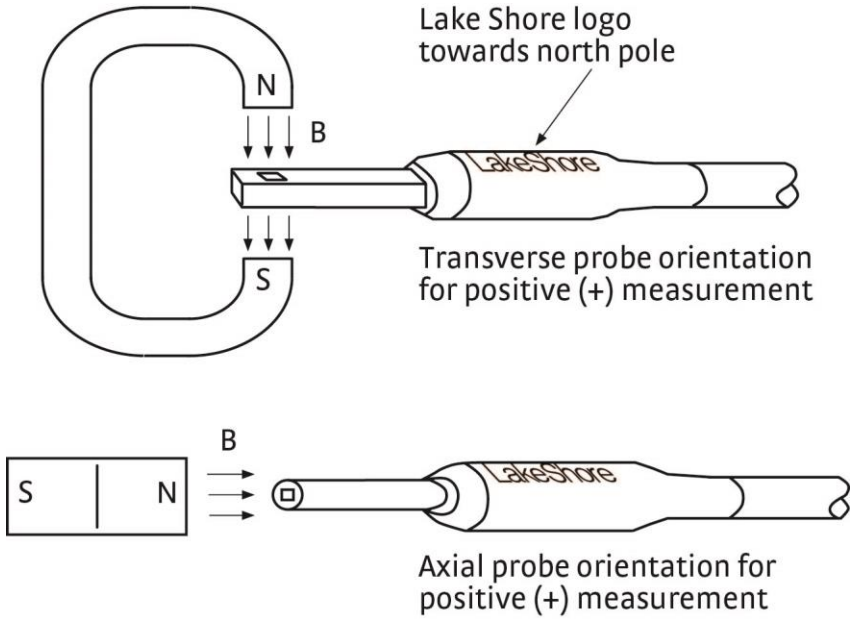


Figure 3-4. Probe Orientation For Positive Measurement

3.5.3 Probe Accuracy Considerations

The user must consider all the possible contributors to the accuracy of the reading. Both the probe and gaussmeter have accuracy specifications that may impact the actual reading. The probe should be zeroed before making critical measurements. The zero probe function is used to null (cancel) out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an open probe (registering the local earth magnetic field). Users wishing to cancel out large magnetic fields should use the Relative function. Refer to Section 4.6.6.

Probe temperature can also affect readings. Refer to the two separate temperature coefficients listed on the specification sheet. The High Stability (HST) probes exhibit a low temperature coefficient of gain due to the inherent thermal stability of the materials used in its construction.

Probe readings are dependent on the angle of the sensor (Hall sensor) in relation to the magnetic field. Maximum output occurs when the flux vector is perpendicular to the plane of the sensor. This is the condition that exists during factory calibration. The greater the deviation from orthogonality (from right angles in either of three axes), the larger the error of the reading. For example, a 5° variance on any one axis causes a 0.4% error, a 10° misalignment induces a 1.5% error, etc. See Figure 3-5.

Tolerance of instrument, probe, and magnet must be considered for making critical measurements. The accuracy of the gaussmeter reading is typically ±0.05% of reading and ±0.005% of range, but the absolute accuracy readings for gaussmeters and Hall probes is a difficult specification to give, because all the variables of the measurement are difficult to reproduce. Differences in alignment and positioning will degrade measurement accuracy and repeatability. Finally, the best probes have an accuracy of ±0.10%. This implies that the absolute accuracy of a magnetic field measurement will not reliably be better than ±0.10% of reading, and is likely to be 0.20%.

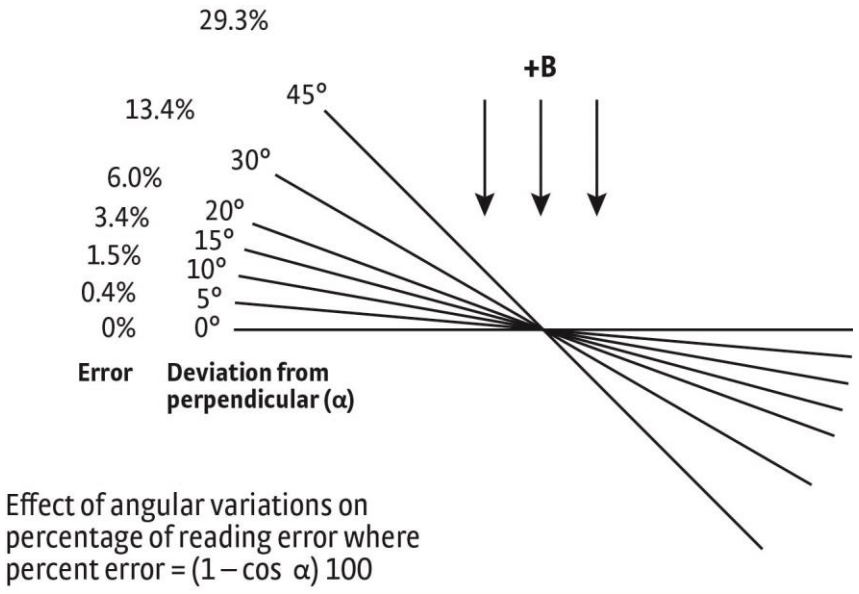
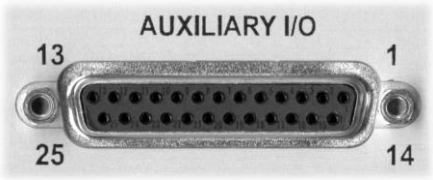


Figure 3-5. Effect Of Angle On Measurements

3.6 AUXILIARY I/O CONNECTION

The Auxiliary connector is a 25 pin D-sub plug. This provides access to the analog outputs and relays. The pins are defined in the following table.



Auxiliary_IO.bmp

Figure 3-6. Auxiliary I/O Connector

Pin	*Description*	*Pin*	*Description*
1	Analog Out 1	14	Ground
2	Analog Out 2	15	Ground
3	Analog Out 3	16	Ground
4	*No Connection*	17	*No Connection*
5	*Internal Use Only*	18	*No Connection*
6	*Internal Use Only*	19	*No Connection*
7	*No Connection*	20	*No Connection*
8	Relay 1 NO	21	*No Connection*
9	Relay 1 COM	22	*No Connection*
10	Relay 1 NC	23	*No Connection*
11	Relay 2 NO	24	*No Connection*
12	Relay 2 COM	25	*No Connection*
13	Relay 2 NC		

Analog Output 1: The first voltage output gives access to amplified voltage signal directly from the probe. This voltage is corrected for the nominal sensitivity of the probe and provides the widest bandwidth of the three voltage outputs. In wideband AC mode, its signal can be viewed on an oscilloscope to observe the shape of AC fields. In peak mode the output can be used to view pulse shape or other characteristic of a momentary signal. Output 1 serves only as a diagnostic tool in DC and narrow band AC modes because modulation the probe signal prevents a clear view of the field response.

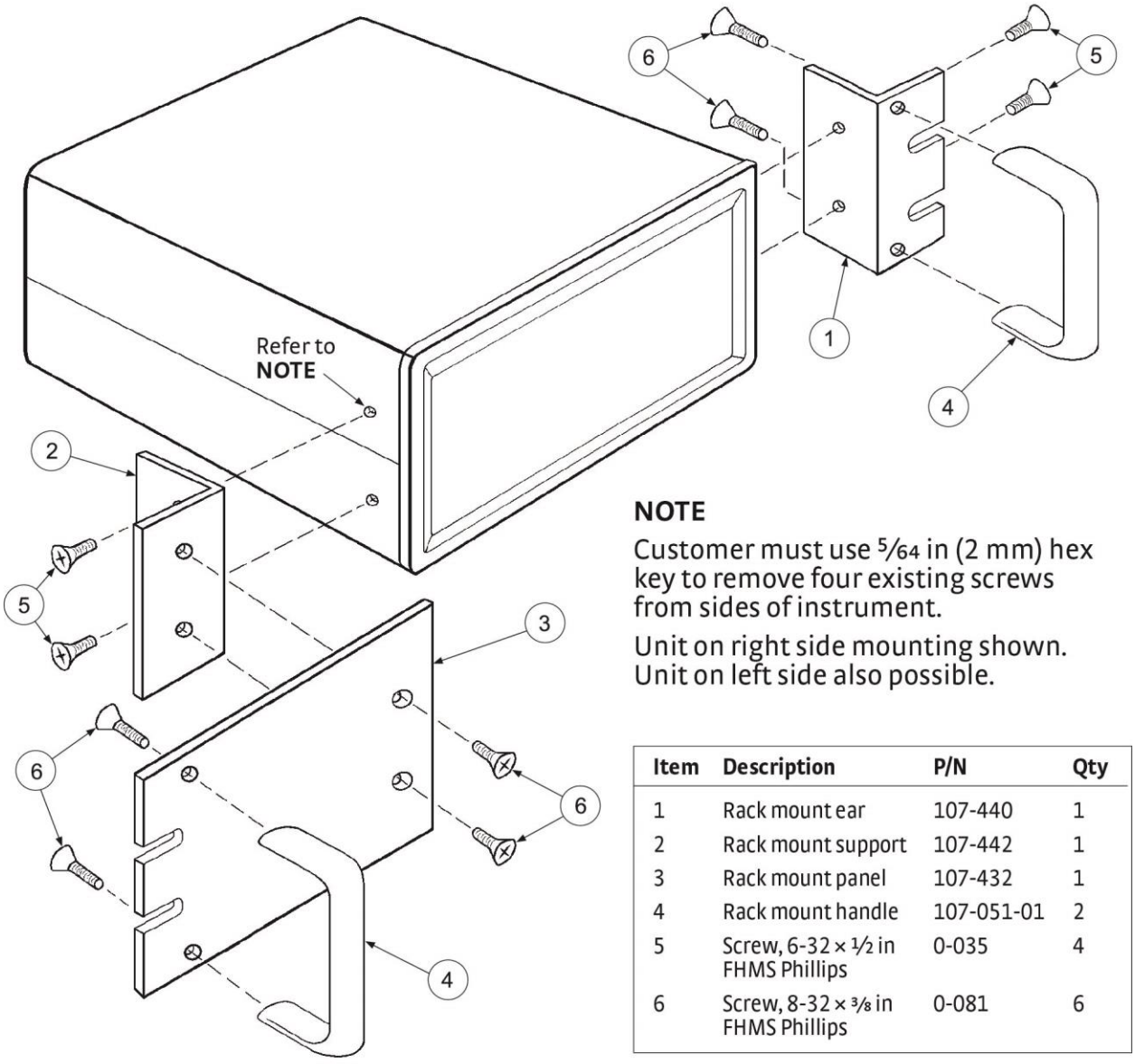
Analog Output 2: The second voltage output provides a voltage proportional to measured field with the benefits of some signal processing. The output is produced by the DSP through a fast D/A converter. The output signal is updated at 40 kHz, giving good response for low to mid frequency fields. Signal quality degrades at high frequency because of the sampling rate. Probe offset correction and correction for the nominal sensitivity of the probe can be performed on this signal.

Analog Output 3: The third voltage output provides a voltage proportional to measured field with the most signal processing of the three outputs. All probe compensation available to the display readings, including temperature compensation, can be performed on this output. The output is produced by the microprocessor through a high-resolution, 16-bit, D/A converter updated at 30 readings per second.

Relay1 and Relay 2: The Model 455 has two mechanical relays designated Relay 1 and Relay 2. The relays are most commonly associated with the high and low alarms, but they can also be controlled manually and used for other purposes. Refer to Section 4.11 for more details.

3.7 RACK MOUNTING

The Model 455 can be installed into a 19-inch rack mount cabinet using the optional Lake Shore Model RM½ Rack-Mount Kit, or the Model RM2 Dual Rack-Mount Shelf. The Rack-Mount Kit contains mounting ears, panel, handles, and screws that adapt the front panel to fit into a 3.5 inch tall, full rack space. Refer to Figure 3-7 and Figure 3-8 for installation details.



Item	Description	P/N	Qty
1	Rack mount ear	107-440	1
2	Rack mount support	107-442	1
3	Rack mount panel	107-432	1
4	Rack mount handle	107-051-01	2
5	Screw, 6-32 × ½ in FHMS Phillips	0-035	4
6	Screw, 8-32 × ⅜ in FHMS Phillips	0-081	6

Figure 3-7. Model RM½ Rack-Mount Kit (P/N 4022)

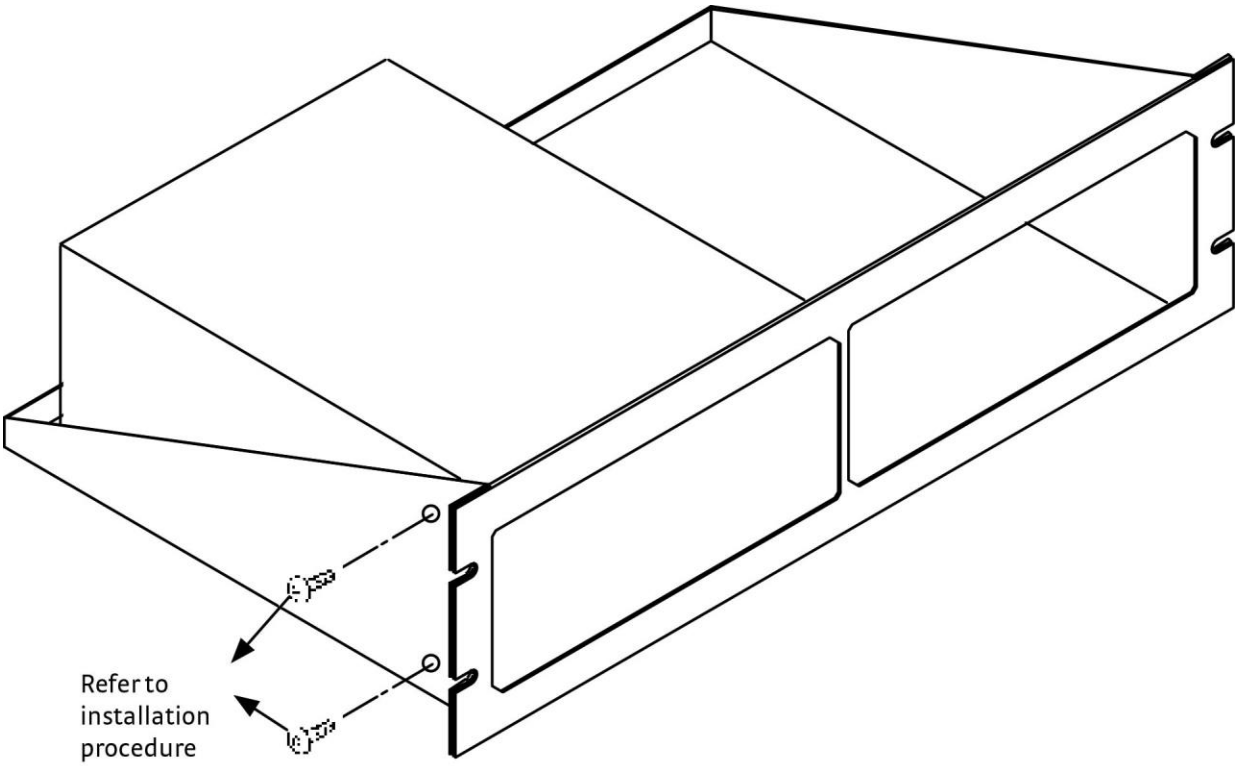


Figure 3-8. Model RM2 Dual Rack-Mount Shelf (P/N 4026)

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CHAPTER 4

OPERATION

4.0 GENERAL

This chapter provides instructions for the general operating features of the Model 455 Gaussmeter. Advanced operation including Probe management is in Chapter 5. Computer interface instructions are in Chapter 6.

4.1 TURNING POWER ON

Verify that the AC line voltage indicator in the fuse drawer window shows the appropriate AC line voltage before turning the instrument on. The instrument may be damaged if it is turned on with the wrong voltage selected. Instructions for checking line voltage selection are given in Section 3.3.1. Attach the power cord and turn on the instrument as described in Section 3.3.4.

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Lake Shore 455
DSP Gaussmeter
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When the Model 455 is turned on the display reads Lake Shore for a few seconds and the alarm beeper sounds briefly to indicate the instrument is initializing. Most instrument setup parameter values are retained when power is off with only a few exceptions. When the instrument is powered on for the first time parameter values are set to their defaults, listed in Table 4-1.

When initialization is complete, field readings will appear on the display. Messages will appear in the reading locations on the display if the instrument has not been properly configured. Refer to Section 8.6 for a list of error messages.

The Model 455 should be allowed to warm up for a minimum of 30 minutes to achieve rated accuracy.

455_Front_3.bmp

Figure 4-1. Model 455 Front Panel

4.2 DISPLAY DEFINITION

In normal operation, the two row by twenty character vacuum fluorescent display provides readings defined by the selected measurement features on the top row, and special information or readings on the bottom row. The bottom row can be configured under most operating conditions (refer to Section 4.4). This paragraph describes features of the display that appear during normal operation including field measurement, temperature measurement, and frequency. Other information displays when using the various functions on the keypad.

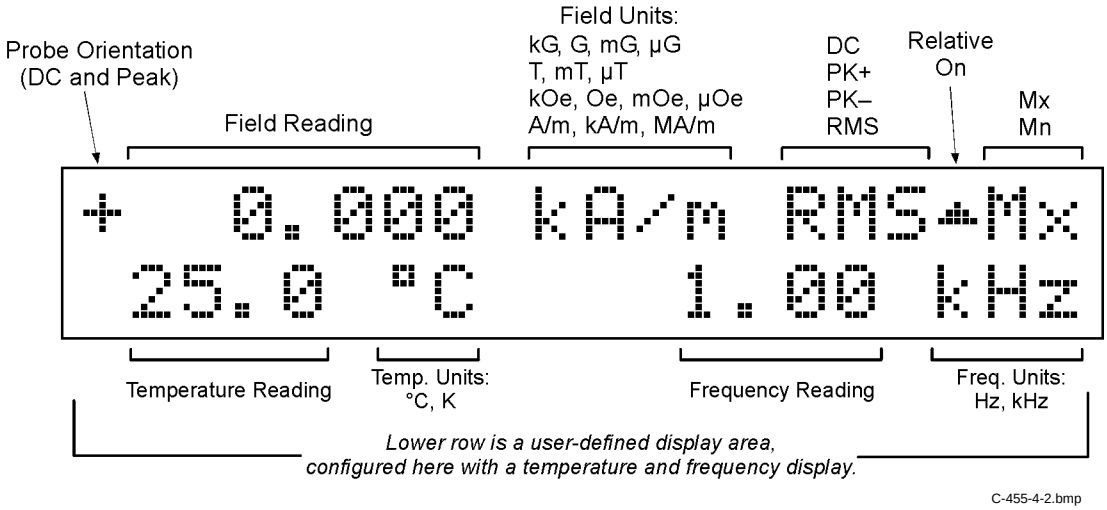


Figure 4-2. Front Panel Display Definition

4.2.1 Display Units

µG, mG, G, kG	Field in Gauss.
µT, mT, T	Field in Tesla
µOe, mOe, Oe, kOe	Field in Oersted
A/m, kA/m, MA/m	Field in Amp/meter
µΩ, mΩ, Ω	Resistance in Ohms
MX, MN	Maximum and Minimum from Max Hold
PK+, PK–	Positive and Negative Peak readings
DC, RMS	DC or RMS mode readings
Hz, kHz	Frequency of RMS fields in Hz
mK, K	Probe Temperature in Kelvin
C	Probe Temperature in Celsius

4.2.2 Display and LED Annunciators

There are also feature annunciators that appear as necessary to indicate additional information. Display annunciators are visible when their associated feature is enabled. In addition to the display annunciators there are three LED annunciators to the right of the display.

Display and LED Annunciators (Continued)

Display Annunciators

Δ	Indicates that the Relative measurement mode is on.
SP	Indicates the Relative setpoint value.

LED Annunciators

Relative	Indicates that the Relative measurement mode is on.
Alarm	On steady when the alarm feature is on, blinks when the alarm is active .
Remote	Indicates that the instrument is under remote control of the computer interface.

4.3 KEYPAD DEFINITION

The Model 455 has 22 keys separated into 3 groups on the instrument front panel.

4.3.1 Key Descriptions

Local	Returns the instrument to Local mode if in Remote (Chapter 6)
Analog Output	Setup Analog Output 3
Display	Configure bottom line of display
Autorange	Turns Auto Range feature ON and OFF.
Zero Probe	Zeros or nulls effects of ambient low level fields from the probe
Interface	Setup computer interface parameters (Chapter 6)
Alarm	Turns Alarm feature ON and OFF, and setup alarm parameters
Relay	Setup Relay feature
Units	Configure units of measurement for Field and Temperature (if available)
Select Range	Manually selects field measurement range
Probe	Setup and view Probe parameters. Extension cable programming
0-9, ±, .	Numeric data entry within a setting sequence

⩙ (Up)	Increments a parameter selection or value in a numerical display
⩛ (Down)	Decrements a parameter selection or value in a numerical display
Escape	Exits from parameter setting sequence without changing the parameter value. Press and hold Escape for 6 seconds to view firmware date and for setting parameters to factory defaults.
Enter	Accepts changes in the parameter setting display. Press and hold Enter to access the Keypad Lock feature.

DC	Select DC Field measurement. Press and hold to select Filter.
RMS	Select AC Root Mean Square (RMS) measurement. Press and hold for RMS mode configuration
Max Hold	Turns Max Hold feature ON and OFF
Peak	Select Peak measurement. Press and hold for peak configuration
Relative	Turns Relative feature ON and OFF.
Reset	Reset max, min or peak readings depending on which measurement is active

4.3.2 General Keypad Operation

The Model 455 uses four basic keypad operations, direct operation, *press and hold*, setting selection and data entry, for the majority of operator interface. A few specialized keypad operations, such as User cable and Probe extension cable programming, are described in the individual operation paragraphs.

Direct Operation: Occurs immediately when the key is pressed. **DC, RMS, Max Hold, Peak, Relative,** and **Reset** are examples of keys that operate this way.

Press and Hold: Occurs when the key is pressed and held for approximately 4 seconds. It is used to modify less frequently changed setup parameters. This operation is described in the individual key paragraphs for the keys that have this available.

Setting Selection: Allows the user to select from a finite list of parameter values. During setting selection the ⩙ and ⩛ keys are used to select a parameter value. **Enter** is used to accept the change and advance to the next parameter. **Escape** will cancel the change to that parameter and return to the normal display. Setting selection screens always include the message: "Select with ⩙⩛".

Data Entry: Allows the user to enter numeric parameter values using the data entry keys that are printed on the key tops. Data entry keys include numbers from 0 to 9, sign, and decimal point. The labels printed above the keys describe the key function during normal operation. When one of the keys is pressed and a data entry sequence is started, the keys follow the data entry functions printed on the key tops. Once the correct parameter value is entered press **Enter** to accept the change and advance to next parameter. Pressing **Escape** once will clear the new value and restart the setting sequence. Pressing **Escape** again will return to the normal display. Data entry screens always include the message: "Enter for", followed by the parameter being set.

Related setting selection and data entry sequences are often chained together under a single key. To skip over a parameter without changing its value press **Enter** before pressing an arrow or number key. To return to the normal display in the middle of a setting sequence press **Escape** before pressing an arrow or number key. Changes "entered" before **Escape** is pressed are kept.

4.4 DISPLAY SETUP

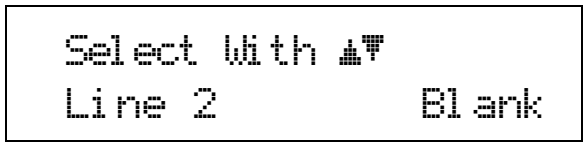
In normal operation, the two row by twenty character vacuum fluorescent display provides magnetic readings on the top row and special information or readings on the bottom row. The user may configure the bottom row of the display.

4.4.1 Two-Line Display Configuration

The Model 455 can be configured to display different values on the bottom line of the display. The following list gives a description of each setting.

Blank	No Bottom line display.
Field	Display the present field reading. This is useful if the top line is used for Max Hold.
Temp/Freq	Display the probe temperature if available and display the frequency if in RMS.
Relative SP	Display the relative setpoint.

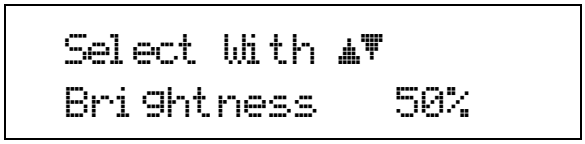
To configure the display, press **Display**. The display configuration screen appears as a prompt for the data to display on the bottom line.



Use the ▲ or ▼ key to select one of the display items, Blank, Field, Temp/Freq, or Relative SP. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.4.2 Display Brightness

To change the brightness, *press and hold* the **Display** key for approximately 4 seconds. The display configuration screen appears as a prompt for display brightness. Operating continuously at 100% brightness will shorten the life of the display. A brightness setting of 75% is recommended for normal operation.



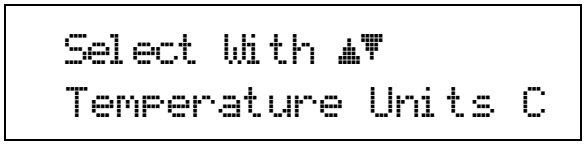
Use the ▲ or ▼ key to select brightness from 25% to 100%. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.5 UNITS

To configure the field measurement units, press **Units**. The units setup screen appears as a prompt for the field measurement units.

Use the ▲ or ▼ key to select the field units, Gauss, Tesla, Oersted, or Amp/meter. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

To configure the temperature measurement units, *press and hold* the **Units** key for approximately 4 seconds. The units setup screen appears as a prompt for the temperature measurement units.



Use the ▲ or ▼ key to select the temperature units, C, or K. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.6 DC MEASUREMENT MODE

To measure static or slowly changing fields, press the **DC** key on the front panel. In DC measurement mode, the keypad and functionality of the Model 455 is optimized to provide the best interaction for DC measurements. The keypad features are described in paragraphs 4.6.1 through 4.6.7.

4.6.1 DC Operation Select Range and Autorange

The Model 455 reads each Lake Shore probe type: High Stability, High Sensitivity, and Ultra-High Sensitivity. The tables below list full scale ranges for each probe sensitivity, along with the **maximum number of digits of display resolution**. Measurement resolution (noise floor) varies depending on probe and application.

High Stability Probe (HST)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±350.000 kG	±35.0000 T	±350.000 kOe	±28.0000 MA/m
±35.0000 kG	±3.50000 T	±35.0000 kOe	±2.80000 MA/m
±3.50000 kG	±350.000 mT	±3.50000 kOe	±280.000 kA/m
±350.000 G	±35.0000 mT	±350.000 Oe	±28.0000 kA/m
±35.0000 G	±3.50000 mT	±35.0000 Oe	±2.80000 kA/m

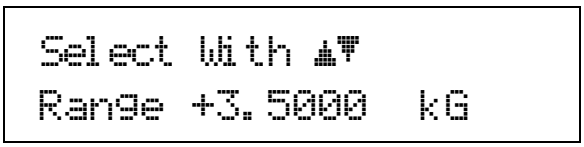
High Sensitivity Probe (HSE)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.0000 kG	±3.50000 T	±35.0000 kOe	±2.80000 MA/m
±3.50000 kG	±350.000 mT	±3.50000 kOe	±280.000 kA/m
±350.000 G	±35.0000 mT	±350.000 Oe	±28.0000 kA/m
±35.0000 G	±3.50000 mT	±35.0000 Oe	±2.80000 kA/m
±3.50000 G	±350.000 µT	±3.50000 Oe	±280.000 A/m

Ultra-High Sensitivity Probe (UHS)

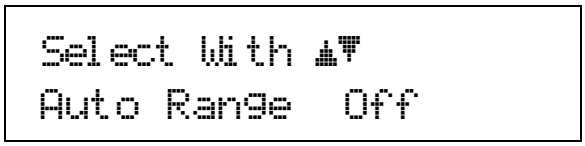
Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.0000 G	±3.50000 mT	±35.0000 Oe	±2.80000 kA/m
±3.50000 G	±350.000 µT	±3.50000 Oe	±280.000 A/m
±350.000 mG	±35.0000 µT	±350.000 mOe	±28.0000 A/m
±35.0000 mG	±3.50000 µT	±35.0000 mOe	±2.80000 A/m

For manual ranging, press the **Select Range** key. The range setup screen appears as a prompt for changing the range.



Use the ▲ or ▼ key to select from the available ranges. Press Enter to accept the new selection and return to the normal display. Press Escape to cancel the new selection and return to the normal display.

Selecting the range this way will disable the Auto Range function. To enable the Auto Range function, press **Autorange**. The autorange setup screen appears as a prompt for turning the Auto Range function on or off.



Use the ▲ or ▼ key to select from Off or On. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

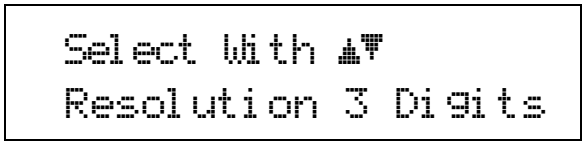
4.6.2 DC Operation Resolution and Filtering

The firmware linear filter is an integral part of the Model 455 DC measurement. It is directly related to measurement resolution, frequency response, and reading rate. Reading rates up to 30 readings per second are only available over the computer interface, but the display will update at 5 readings per second independent of filter configuration.

The resolution can be set from 3¾ to 5¾ digits. The table below shows how the resolution is related to the reading rate and the frequency response.

Display Setting	Number of Digits	3 dB Frequency	Maximum Reading Rate
3	3¾	100 Hz	30 readings/second
4	4¾	10 Hz	30 readings/second
5	5¾	1 Hz	10 readings/second

To configure the resolution, *press and hold* the **DC** key for approximately 4 seconds. The following screen appears as a prompt for DC resolution setting.



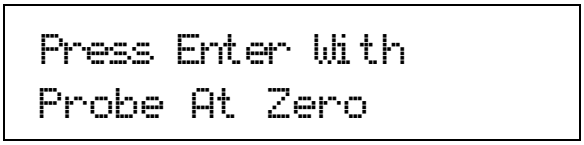
Use the ▲ or ▼ key to select from 3, 4, or 5 digits. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.6.3 DC Operation Zero Probe

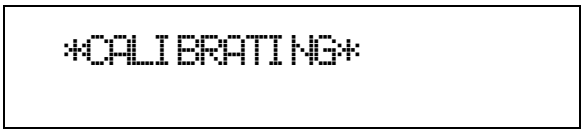
The zero probe function cancels out the zero offset of the probe or small DC magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an unshielded probe (registering Earth's local magnetic field). The zero probe function should be used any time a probe is changed, when operating conditions such as temperature change significantly, and periodically during normal use. To cancel large magnetic fields, use the Relative function.

NOTE: For best results, allow the instrument and probe to warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

To zero the probe in the zero gauss chamber, first allow the temperature of the probe and chamber to equalize. (A large temperature discrepancy affects the quality of the calibration.) Carefully place the probe tip into the chamber. Orientation of the probe is not critical. Once inserted, press **Zero Probe**. The following screen appears as a prompt to zero the probe.



Press **Enter** to begin the zero probe process. Press **Escape** to cancel the sequence and return to the normal display. During the zero probe process, the calibration message below will appear. Do not move the probe until the zero probe process is complete and the display returns to the normal display.



If during the zero probe process, the measured offset is larger than expected, the Model 455 will put up the following message alerting to the user that there may be a problem with the probe.

The Model 455 will continue to operate with the offset correction, but it will be up to the individual to investigate the nature of the offset.

4.6.4 DC Operation Max Hold

The Max Hold function captures the largest (Maximum) or smallest (Minimum) field readings or field magnitudes since the last **Reset** press. To turn the Max Hold feature on, press the **Max Hold** key. The following screen will appear for approximately 3 seconds.

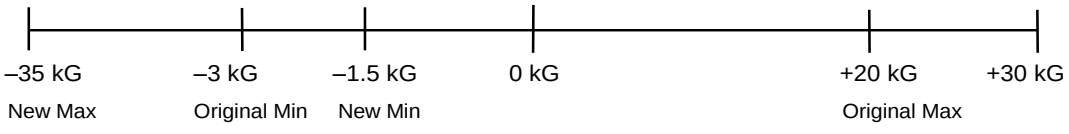
To turn the Max Hold feature off, press the **Max Hold** key again.

4.6.4.1 Magnitude or Algebraic

The Max Hold function can be configured to use the magnitude of the field reading only, or to include the sign and treat the readings algebraically. In Magnitude mode, the maximum reading is the field measurement with the largest magnitude, independent of sign, since the last reset.

Example: If the present maximum reading is +20 kG and the instrument measures –35 kG, the –35 kG becomes the new maximum reading.

If the minimum reading is –3.0 kG and the instrument measures –1.5 kG, the –1.5 kG becomes the new minimum reading.

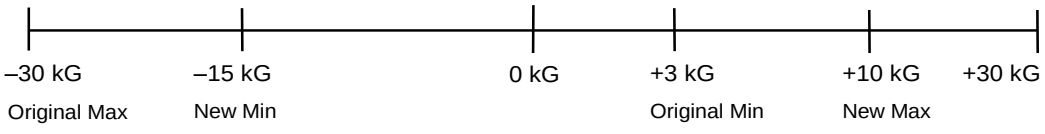


Example of operation Magnitude

In Algebraic mode, the field values are compared mathematically with the sign included. The maximum reading is the larger signed value since the last reset.

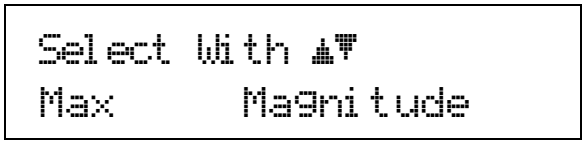
Example: If the present maximum reading is –30 kG and the instrument measures +10 kG, the +10 kG becomes the new maximum reading.

If the minimum reading is +3.0 kG and the instrument measures –15 kG, the –15 kG becomes the new minimum reading.



Example of operation Algebraic

To configure the Max Hold measurement mode, *press and hold* the **Max Hold** key for approximately 4 seconds. The max hold setup screen appears as a prompt for selecting the measurement mode.

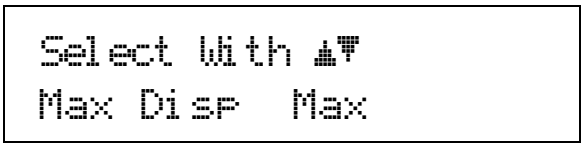


Use the ▲ or ▼ key to select Magnitude or Algebraic. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

4.6.4.2 Max/Min Display Setting

Typically the maximum reading (Max) is displayed on the top line when the Max Hold feature is on. Sometimes it may be beneficial to display the minimum reading (Min) on the top line instead of the maximum. The user may also display both the maximum and minimum readings, with the maximum reading on the top line and the minimum reading on the bottom line. **Displaying both will override the two line display configuration when Max Hold is active** (refer to Section 4.4.1).

To configure the Max Hold display setting, continue from the Max Hold mode screen or *press and hold* **Max Hold** and then press **Enter** until the following screen appears as a prompt for Max Hold display setup.



Use the ▲ or ▼ key to select Max, Min, or Both. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.6.5 DC Operation Reset

If the Max Hold function is on and the **Reset** key is pressed, the maximum and minimum readings are cleared and reset with the present field reading.

4.6.6 DC Operation Relative

The relative function lets the user see small variations in larger fields. When the relative function is on, the relative readings will appear on the top line of the display including the small delta sign (▲) signifying the relative display. The displayed reading is equal to the present field value minus the relative setpoint.

The relative setpoint can be configured to be the present field reading or it can be a user defined value. The relative setpoint can be displayed on the bottom display. Refer to Section 4.4.1.

To configure the relative setpoint, *press and hold* the **Relative** key for approximately 4 seconds. The relative setup screen appears as a prompt for selecting the source of the relative setpoint.

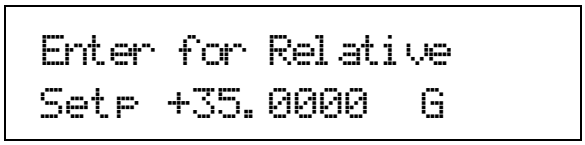
Use the ▲ or ▼ key to select Present Field or User Defined. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

To turn the relative function on, press the **Relative** key. The following screen will appear for approximately 3 seconds and the Relative LED will light.

The relative function also interacts with other features. Relative can be used with Max Hold to display the maximum relative reading. To turn the Relative function off, press the **Relative** key.

If the relative mode is configured to use the present field as the setpoint, the Off to On transition will capture the field reading to use as the setpoint.

If a User Defined setpoint is selected, the following screen appears as a prompt for entering the setpoint after the Relative On display disappears.



Use the data entry keys to enter the high setpoint between ±350 kG or equivalent depending on selected field units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M, depending on selected field units. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

NOTE: The Relative Setpoint entry screen also appears under the *press and hold* feature of the **Relative** key if relative is configured for a user defined setpoint.

4.6.7 DC Operation Analog Output 1 and 2

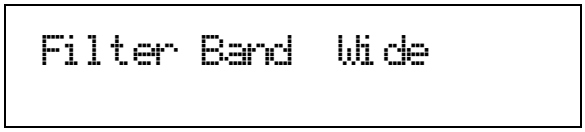
In the DC measurement mode, the signal available at Analog Output 1 may only be useful as a verification of the Model 455 measurement hardware. The signal contains the 5 kHz modulation of the current source making it difficult to use as an accurate field representation.

Analog Output 2 provides a DC voltage proportional to the displayed field through a high-speed D/A converter. This voltage is corrected for the nominal sensitivity of the probe and adjusted for the zero offset. The output is updated at a rate of 40,000 readings per second.

4.7 RMS MEASUREMENT MODE

To measure periodic, AC fields, press the **RMS** key on the front panel. In RMS measurement mode, the keypad and functionality of the Model 455 is optimized to provide the best interaction for RMS measurements. The keypad features are described in paragraphs 4.7.1 through 4.7.8.

The instrument communicates the present RMS measurement band when entering RMS mode. When the RMS key is pressed, the following message will appear for approximately 3 seconds. Note: This display screen is an example of having the AC wide band mode selected (refer to Section 4.7.2 for measurement band configuration).



4.7.1 RMS Operation Select Range and Autorange

The Model 455 reads each Lake Shore probe type: High Stability, High Sensitivity, and Ultra-High Sensitivity. The tables below list full scale ranges for each probe sensitivity, along with the display resolution. Measurement resolution (noise floor) varies depending on probe and application, but the Model 455 can typically measure signals as small as 0.1% of full scale range.

High Stability Probe (HST)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±350.00 kG	±35.000 T	±350.00 kOe	±28.000 MA/m
±35.000 kG	±3.5000 T	±35.000 kOe	±2.8000 MA/m
±3.5000 kG	±350.00 mT	±3.5000 kOe	±280.00 kA/m
±350.00 G	±35.000 mT	±350.00 Oe	±28.000 kA/m
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m

High Sensitivity Probe (HSE)

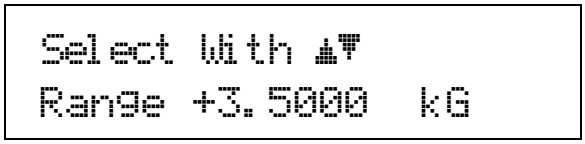
Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.000 kG	±3.5000 T	±35.000 kOe	±2.8000 MA/m
±3.5000 kG	±350.00 mT	±3.5000 kOe	±280.00 kA/m
±350.00 G	±35.000 mT	±350.00 Oe	±28.000 kA/m
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m
±3.5000 G	±350.00 µT	±3.5000 Oe	±280.00 A/m

Ultra-High Sensitivity Probe (UHS)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m
±3.5000 G	±350.00 µT	±3.5000 Oe	±280.00 A/m
±350.00 mG	±35.000 µT	±350.00 mOe	±28.000 A/m
±35.000 mG	±3.5000 µT	±35.000 mOe	±2.8000 A/m

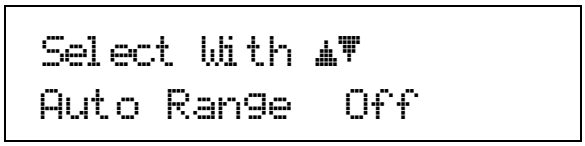
RMS Operation Select Range and Autorange (Continued)

For manual ranging, press the **Select Range** key. The range setup screen appears as a prompt for changing the range.



Use the ▲ or ▼ key to select from the available ranges. Press Enter to accept the new selection and return to the normal display. Press Escape to cancel the new selection and return to the normal display.

Selecting the range this way will disable the Auto Range function. To enable the Auto Range function, press Autorange. The screen appears as a prompt for turning the Auto Range function on or off.



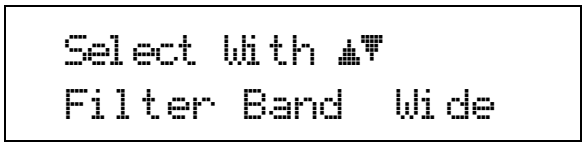
Use the ▲ or ▼ key to select from Off or On. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

NOTE: Autorange should not be used when measuring a small RMS field in the presence of a larger DC background.

4.7.2 RMS Measurement Band

The Model 455 offers two RMS measurement bands to improve the overall RMS measurement performance. The instrument may be configured to use a DC current to excite the Hall sensor (Wide Band) or an AC current to excite the Hall sensor (Narrow Band).

To configure the RMS Measurement band for the RMS measurement, *press and hold* the RMS key for approximately 4 seconds. The RMS band setup screen appears as a prompt for filter band setting.



Use the ▲ or ▼ key to select from Wide or Narrow. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

4.7.3 RMS Operation Frequency Measurement

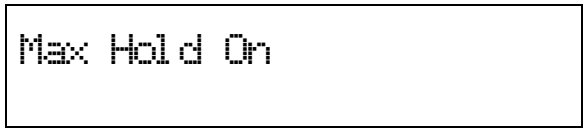
With certain limitations, the Model 455 Gaussmeter is capable of measuring and displaying the frequency of an AC magnetic field. The frequency is calculated using a zero-crossing counter, so the indicated value is only valid for robust fields with a single, dominant frequency. Because of sampling rate limitations, the reading is correct only up to 20 kHz. Refer to Section 4.4.1 to configure the display to indicate frequency.

4.7.4 RMS Operation Reading Rate

In RMS measurement mode, the reading update rate is 30 readings per second, only available over the computer interface. The display will update at 5 readings per second independent of the filter setting.

4.7.5 RMS Operation Max Hold

The Max Hold function captures the largest (Maximum) or smallest (Minimum) RMS field readings since the last **Reset** press. To turn the Max Hold feature on, press the **Max Hold** key. The following screen will appear for approximately 3 seconds.

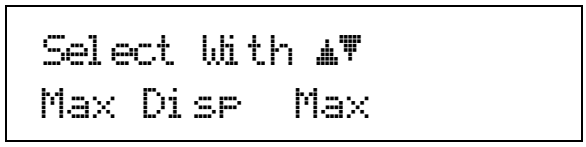


To turn the Max Hold feature off, press the **Max Hold** key again.

4.7.5.1 Max/Min Display Setting

Typically the maximum reading (Max) is displayed on the top line when the Max Hold feature is on. Sometimes it may be beneficial to display the minimum reading (Min) on the top line instead of the maximum. The user may also display both the maximum and minimum readings, with the maximum reading on the top line and the minimum reading on the bottom line. **Displaying both will override the two line display configuration when Max Hold is active** (refer to Section 4.4.1).

To configure the Max Hold display setting, continue from the Max Hold mode screen or *press and hold* **Max Hold** and then press **Enter** until the following screen appears as a prompt for Max Hold display setup.



Use the ▲ or ▼ key to select Max, Min, or Both. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.7.6 RMS Operation Reset

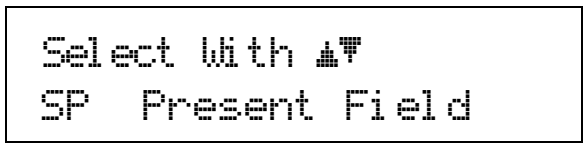
If the Max Hold function is on and the **Reset** key is pressed, the maximum and minimum readings are cleared and reset with the present field reading.

4.7.7 RMS Operation Relative

The relative function lets the user see small variations in larger fields. When the relative function is on, the relative readings will appear on the top line of the display including the small delta sign (▲) signifying the relative display. The displayed reading is equal to the present field value minus the relative setpoint.

The relative setpoint can be configured to be the present field reading or it can be a user defined value. The relative setpoint can be displayed on the bottom display. Refer to Section 4.4.1.

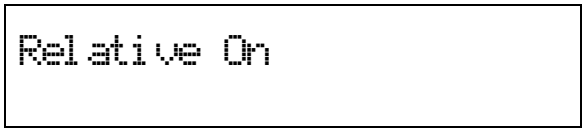
To configure the relative setpoint, *press and hold* the **Relative** key for approximately 4 seconds. The relative setup screen appears as a prompt for selecting the source of the relative setpoint.



Use the ▲ or ▼ key to select Present Field or User Defined. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

RMS Operation Relative (Continued)

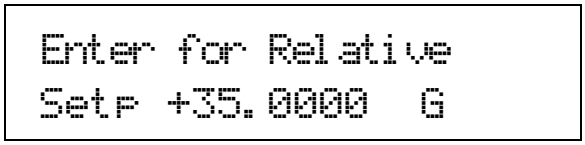
To turn the relative function on, press the **Relative** key. The following screen will appear for approximately 3 seconds and the Relative LED will light.



The relative function also interacts with other features. Relative can be used with Max Hold to display the maximum relative reading. To turn the Relative function off, press the **Relative** key.

If the relative mode is configured to use the present field as the setpoint, the Off to On transition will capture the field reading to use as the setpoint.

If a User Defined setpoint is selected, the following screen appears as a prompt for entering the setpoint after the Relative On display disappears.



Use the data entry keys to enter the relative setpoint between ±350 kG or equivalent depending on selected field units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of μ, m, blank, k or M, depending on selected field units. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

4.7.8 RMS Operation Analog Output 1 and 2

If the instrument is configured in Wide Band RMS measurement mode, Analog Output 1 is a real-time analog signal proportional to the AC magnetic field and scaled to ±3.5 volts for full scale of selected range, except for the lowest range which is scaled to ±0.35 volts for full scale range. The output has a frequency range of 1 Hz to 20 kHz.

If the instrument is configured in Narrow Band RMS measurement mode, Analog Output 1 may only be useful as a verification of the Model 455 measurement hardware. The signal contains the 5 kHz modulation of the current source making it difficult to use as an accurate field representation.

Analog Output 2 provides an AC voltage proportional to the AC magnetic field through a high-speed D/A converter. This voltage is corrected for the nominal sensitivity of the probe. The output is updated at a rate of 40,000 readings per second. The Analog Output 2 is equipped with a two-pole analog lowpass filter at 145 kHz. The individual D/A samples are still visible and the signal may be improved with the addition of external analog filters.

4.8 PEAK MEASUREMENT MODE

To measure pulsed or periodic fields, press the **Peak** key on the front panel. In Peak measurement mode, the keypad and functionality of the Model 455 is optimized to provide the best interaction for Peak measurements. The keypad features are described in the following paragraphs.

NOTE: Max Hold is not offered for Peak Measurement Mode.

4.8.1 Peak Operation Select Range

The Model 455 reads each Lake Shore probe type: High Stability, High Sensitivity, and Ultra-High Sensitivity. The tables below list full scale ranges for each probe sensitivity, along with the display resolution. Measurement resolution (noise floor) varies depending on probe and application.

High Stability Probe (HST)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±350.00 kG	±35.000 T	±350.00 kOe	±28.000 MA/m
±35.000 kG	±3.5000 T	±35.000 kOe	±2.8000 MA/m
±3.5000 kG	±350.00 mT	±3.5000 kOe	±280.00 kA/m
±350.00 G	±35.000 mT	±350.00 Oe	±28.000 kA/m
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m

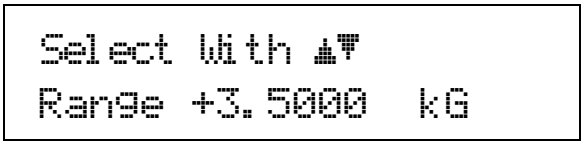
High Sensitivity Probe (HSE)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.000 kG	±3.5000 T	±35.000 kOe	±2.8000 MA/m
±3.5000 kG	±350.00 mT	±3.5000 kOe	±280.00 kA/m
±350.00 G	±35.000 mT	±350.00 Oe	±28.000 kA/m
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m
±3.5000 G	±350.00 µT	±3.5000 Oe	±280.00 A/m

Ultra-High Sensitivity Probe (UHS)

Gauss	Tesla	Oersted	Amp/meter
Range and Resolution	Range and Resolution	Range and Resolution	Range and Resolution
±35.000 G	±3.5000 mT	±35.000 Oe	±2.8000 kA/m
±3.5000 G	±350.00 µT	±3.5000 Oe	±280.00 A/m
±350.00 mG	±35.000 µT	±350.00 mOe	±28.000 A/m
±35.000 mG	±3.5000 µT	±35.000 mOe	±2.8000 A/m

For manual ranging, press the **Select Range** key. The screen appears as a prompt for changing the range.



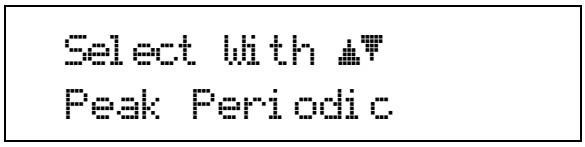
Use the ▲ or ▼ key to select from the available ranges. Press Enter to accept the new selection and return to the normal display. Press Escape to cancel the new selection and return to the normal display.

NOTE: The Auto Range function is not offered for Peak Pulse measurements.

4.8.2 Peak Operation Periodic/Pulse Setup

The Peak measurement mode can be configured to measure pulsed fields or the maximum amplitude of periodic fields. In periodic mode, the instrument follows the peak amplitude of the periodic signal. This may be useful in determining additional information about AC fields, such as crest factor. Pulsed fields with a minimum pulse width of 50 µs can be captured using the pulse measurement mode. Once captured, these readings will only change if a larger peak is measured, or if the **Reset** key is pressed.

To setup the periodic or pulse feature, *press and hold* the **Peak** key for approximately 4 seconds. The Peak configuration screen appears as a prompt for selecting Periodic or Pulse measurements.



Use the ▲ or ▼ key to select from Periodic or Pulse. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

4.8.3 Peak Operation Display Setting

Typically the positive peak reading (PK+) is displayed on the top line when in Peak measurement mode. Sometimes it may be beneficial to display the negative peak reading (PK–) on the top line instead of the maximum. The user may also display both peak readings, with the positive reading on the top line and the negative reading on the bottom line. **Displaying both will override the two line display configuration when Peak is active** (refer to Section 4.4.1).

To configure the Peak display setting, continue from the Periodic/Pulse selection screen or *press and hold* **Peak** and then press **Enter** until the following screen appears as a prompt for Peak display setup.

Use the ▲ or ▼ key to select PK+, PK-, or Both. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.8.4 Peak Operation Reset

In Peak Measurement mode, the **Reset** key is used to clear any captured pulsed readings.

4.8.5 Peak Operation Frequency Measurement

In Peak measurement, the frequency is only measurable in Periodic mode. The frequency is calculated using a zero-crossing counter. The frequency measurement is only valid for robust fields with a single, dominant frequency. Refer to Section 4.4.1 to configure the display for frequency.

4.8.6 Peak Operation Relative

The relative function lets the user see small variations in larger fields. When the relative function is on, the relative readings will appear on the top line of the display including the small delta sign (▲) signifying the relative display. The displayed reading is equal to the present field value minus the relative setpoint.

The relative setpoint can be configured to be the present field reading or it can be a user defined value. The relative setpoint can be displayed on the bottom display. Refer to Section 4.4.1.

To configure the relative setpoint, *press and hold* the **Relative** key for approximately 4 seconds. The relative setup screen appears as a prompt for selecting the source of the relative setpoint.

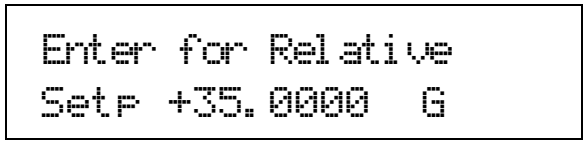
Use the ▲ or ▼ key to select Present Field or User Defined. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

To turn the relative function on, press the **Relative** key. The following screen will appear for approximately 3 seconds and the Relative LED will light.

The relative function also interacts with other features. Relative can be used with Max Hold to display the maximum relative reading. To turn the Relative function off, press the **Relative** key.

If the relative mode is configured to use the present field as the setpoint, the Off to On transition will capture the field reading to use as the setpoint.

If a User Defined setpoint is selected, the following screen appears as a prompt for entering the setpoint after the Relative On display disappears.



Use the data entry keys to enter the high setpoint between ±350 kG or equivalent depending on selected field units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M, depending on selected field units. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

4.8.7 Peak Operation Analog Output 1 and 2

In Peak measurement mode, Analog Output 1 is a real-time analog signal proportional to the magnetic field and scaled to ±3.5 volts for full scale of selected range, except for the lowest range which is scaled to ±0.35 volts for full scale range. The output has a frequency range of 5 Hz to 20 kHz. This output will be useful in both periodic and pulse measurements, for viewing the shape of the field.

Analog Output 2 provides a live AC voltage proportional to the AC magnetic field going into the peak capture algorithm. This voltage is corrected for the nominal sensitivity of the probe. The output is updated at a rate of 40,000 readings per second. The Analog Output 2 is equipped with a two-pole analog lowpass filter at 145 kHz. The individual D/A samples are still visible and the signal may be improved with the addition of external analog filters.

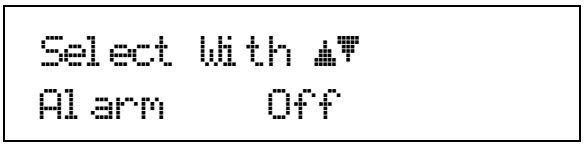
4.9 TEMPERATURE MEASUREMENT

The Model 455 is capable of measuring the temperature of the probe, if the probe is equipped with a temperature sensor and a temperature compensation table. The probe temperature can be displayed as Kelvin or in degrees Celsius. Refer to Section 4.4.1 for display setup.

4.10 ALARM

The alarm gives an audible and visual indication when the field value is outside or inside a user-specified range. When the alarm feature is turned on, the LED annunciator will be on. If any alarm is active, the LED will blink at a steady rate. An audible alarm beeper can be programmed to sound if any alarm is active. Two relays can also be programmed to follow alarm operation, see Section 4.11.

Press the **Alarm** key to begin alarm setup. The following alarm setup screen appears as a prompt for turning the alarm feature on or off.

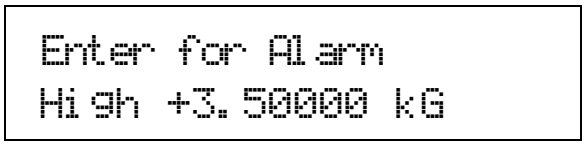


Use the ▲ or ▼ key to select Off or On. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

The next alarm setup screen appears as a prompt for the low alarm setpoint value.

Use the data entry keys to enter the low setpoint between ±350 kG or equivalent depending on selected field units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M, depending on selected field units. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

The next alarm setup screen appears as a prompt for the high alarm setpoint value.



Use the data entry keys to enter the high setpoint between ±350 kG or equivalent depending on selected units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

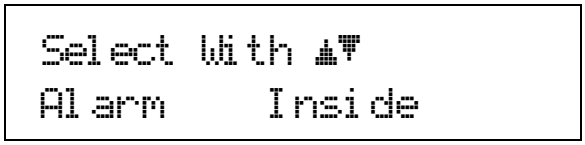
The alarm may be configured to use the magnitude of the field reading only (ignoring the sign), or to include the sign and treat the readings algebraically.

To configure the alarm for magnitude or algebraic mode, *press and hold* the **Alarm** key for approximately 4 seconds. The following alarm setup screen appears as a prompt for using the alarm in magnitude or algebraic mode.

Use the ▲ or ▼ key to select from Magnitude or Algebraic. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

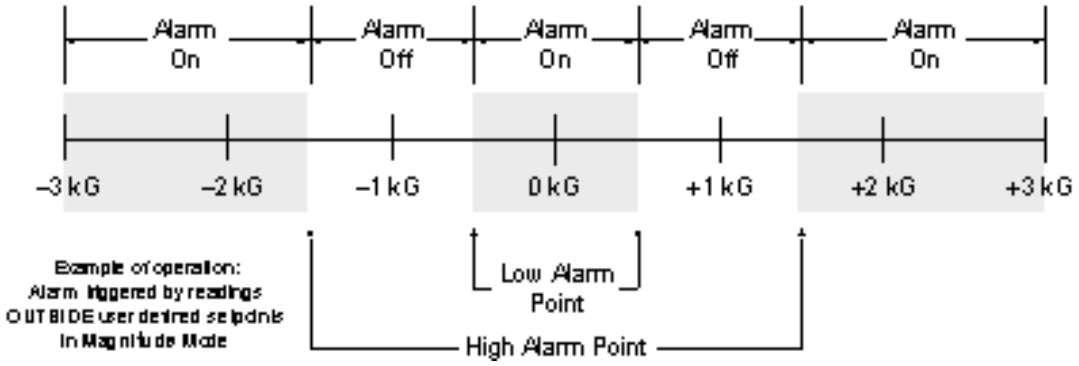
When the alarm feature is used to detect an error condition an active alarm state is expected when the field reading is higher than the high alarm setpoint or below the low alarm setpoint. This operation is achieved by setting the inside/outside parameter to outside. It is called outside because the alarm is active when the reading is outside the range of the two setpoints. During magnet testing or sorting it is often desirable to have the alarm active when the field reading is inside or between the two setpoints. This operation is achieved by setting the inside/outside parameter to inside.

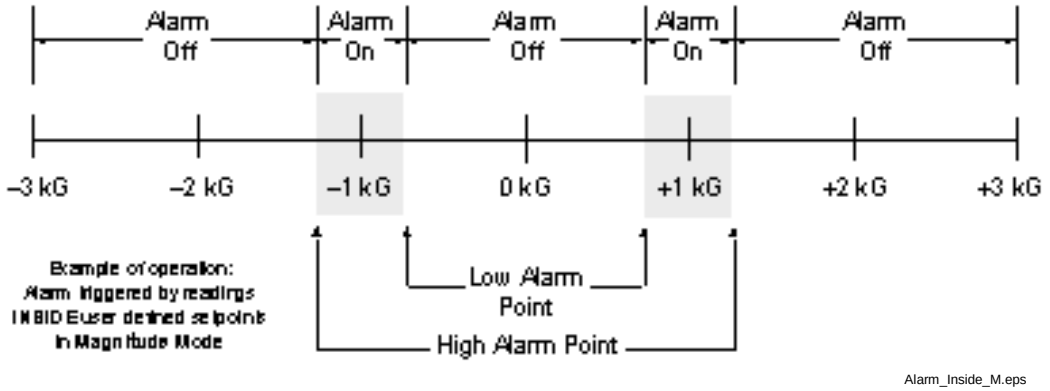
To configure the Alarm inside/outside setting, continue from the magnitude/algebraic mode screen or *press and hold* **Alarm** and then press **Enter** until the following screen appears as a prompt for selecting the inside/outside setting.



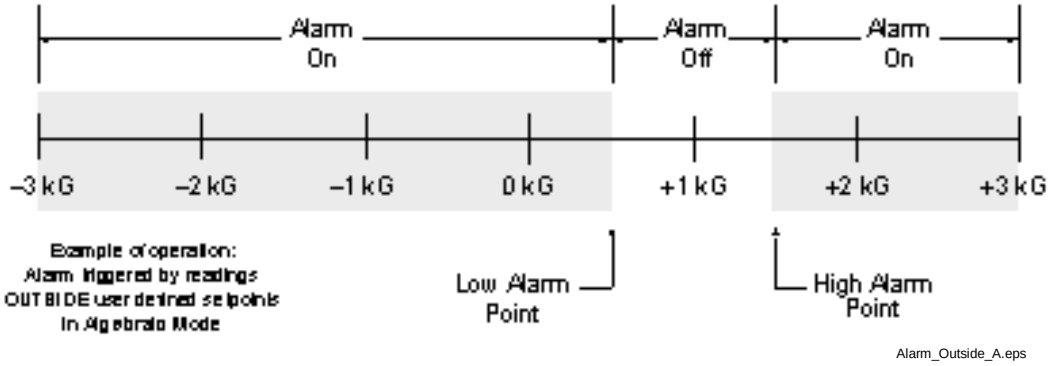
Use the ▲ or ▼ key to select from Inside or Outside. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

The following images demonstrate different combinations of Inside/Outside with Magnitude or Algebraic measurements.

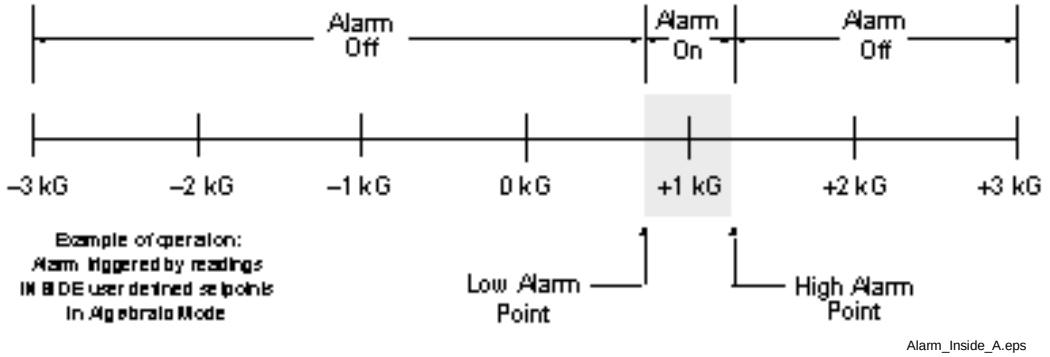




Alarm_Inside_M.eps



Alarm_Outside_A.eps



Alarm_Inside_A.eps

The Model 455 has an audible alarm annunciator or beeper. The beeper will sound when the instrument is in an active alarm state. If the sound of the beeper is not appropriate for your application, it can be turned on or off by the user.

To configure the beeper, continue from the alarm inside/outside setup screen or *press and hold* **Alarm** and then press **Enter** until the following screen appears as a prompt for configuring the beeper.

Use the ▲ or ▼ key to select from Off or On. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

4.11 RELAYS

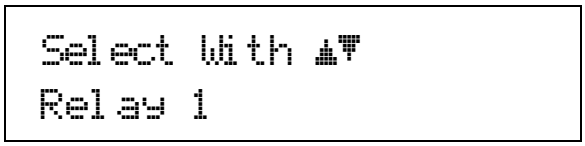
The Model 455 has two mechanical relays designated Relay 1 and Relay 2. The relays are most commonly associated with the high and low alarms, but they can also be controlled manually and used for other purposes. Both relays default to their normal state when instrument power is turned off.

The relays have two modes of operation:

Manual: The relay is turned off (normal) or on (active) manually from the front panel or over computer interface.

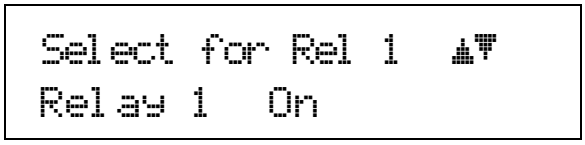
Alarm: The relay is configured to follow the operation of the alarms. The user can tie the action of the relay to the high alarm, low alarm or both alarms. The relay is activated any time the associated alarm is active.

To begin the relay setup process, press the **Relay** key. The following relay setup screen appears as a prompt for relay selection.



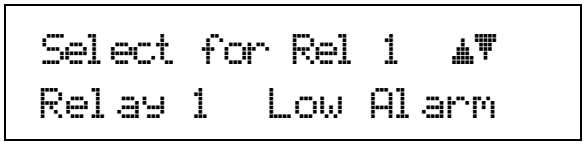
Use the ▲ or ▼ key to select Relay 1 or Relay 2. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

The next relay setup screen appears as a prompt for operating mode.



Use the ▲ or ▼ key to select the relay mode for manual operation (Off, On) or to follow the Alarm operation. Press **Enter** to accept the new selection and continue. If alarm is selected the next setting screen will appear, otherwise the instrument will return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

If the relay is in alarm mode, the next relay setup screen appears as a prompt for an alarm selection.



Use the ▲ or ▼ key to select low, high or both alarms. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.12 ANALOG OUTPUT 3

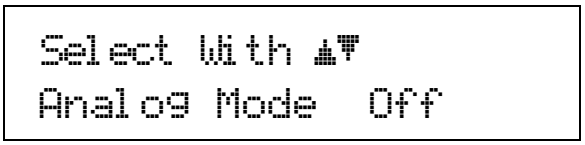
The Analog Output 3 provides a DC voltage proportional to the displayed field. The displayed field reading may be corrected for probe nonlinearity, zero offset, and temperature. This output has an update rate of 30 readings per second. By default the instrument is configured so that ±3.5 volts will equal ±full scale for the selected range. The DC voltage of Analog Output 3 can be configured so that ±10 volts (maximum) will equal ±full scale for the selected range. The high and low limits can be configured so that lower voltages will equal ±full scale for the selected range.

4.12.1 Analog Output 3 Mode Setting

Analog Output 3 may be configured in four different modes of operation. The following list gives a description of each mode.

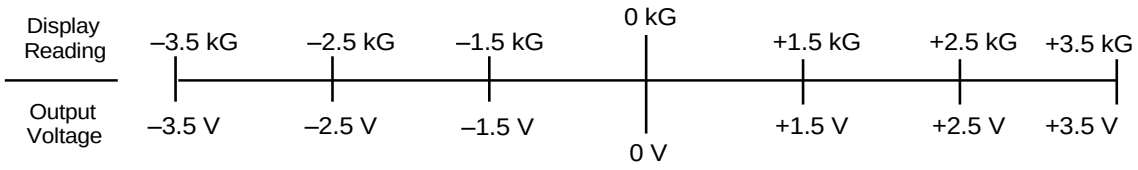
Off	The output of Analog 3 will be zero volts.
Default	±3.5 volts will equal ±full scale for the selected range.
User Def	±10 volts will equal user defined field values.
Manual	The output of Analog 3 can be manually set as a percent in the range ±100%.

To configure the Analog Output 3 mode, press the **Analog Output** key. The analog setup screen appears as a prompt for selecting the mode of operation.

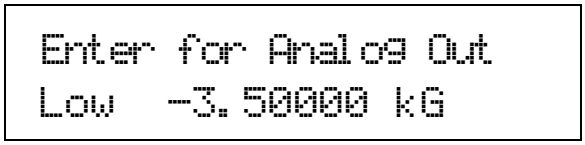


Use the ▲ or ▼ key to select from Off, Default, User Defined, or Manual. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

If the instrument is configured for Default, the following image represents the displayed field versus voltage output for the 3.5 kG range. Scale changes with range.



If the User Defined mode is selected, the next analog setup screen appears as a prompt for the low setpoint value. This value represents the reading at which the **Analog Output 3 will be -10 volts**.



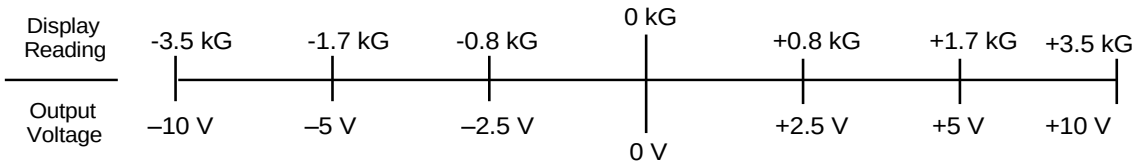
Use the data entry keys to enter the low setpoint between ±350 kG or equivalent depending on selected field units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M, depending on selected field units. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

The next analog setup screen appears as a prompt for the high setpoint value. This value represents the reading at which the **Analog Output 3 will be +10 volts**.

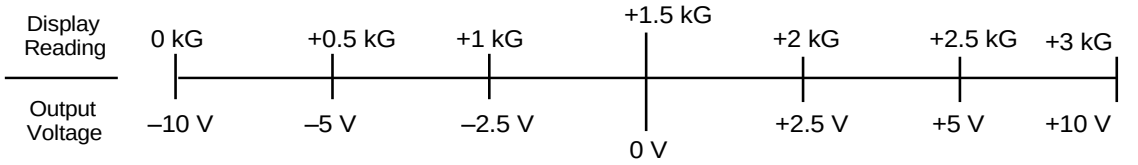
```
Enter for Analog Out
High +3.50000 kG
```

Use the data entry keys to enter the high setpoint between ±350 kG or equivalent depending on selected units. Enter the numeric value first. Press **Enter** to accept the new value and advance to the units multiplier. Use the ▲ or ▼ key to select a units multiplier of µ, m, blank, k or M. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

The following example demonstrates the User Defined Range with the setpoints entered above.



The following example is an asymmetrical scaling which demonstrates the versatility of user-selectable scaling.



If the Manual mode is selected, the manual entry screen appears following the analog mode setting screen. The setting range is from 0% to 100% (if unipolar) or from –100% to 100% (if bipolar), with a setting resolution of 0.001%. A value of +100% represents an output of 10 V and a value of –100% represents an output of –10V. The manual entry screen appears as a prompt for setting the Analog Output 3 voltage.

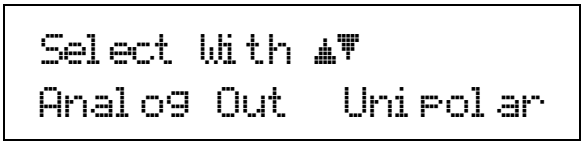
```
Enter for Analog
Man  +10.000 %
```

Use the data entry keys to enter the manual output value between 0 and 100 (unipolar) or –100 and 100 (bipolar). Press **Enter** to accept the new value and return to the normal display. Press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

4.12.2 Analog Output 3 Polarity

The Analog Output 3 can be configured to operate either in a unipolar fashion (output from 0 volts to +10 volts) or in a bipolar fashion (output from –10 volts to +10 volts).

To configure the Analog Output 3 polarity, *press and hold* the **Analog** key for approximately 4 seconds. The following screen appears as a prompt for configuring the polarity.

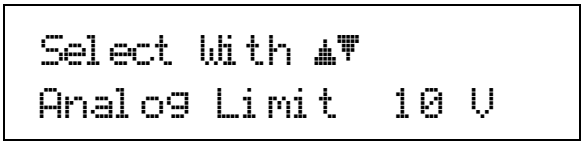


Use the ▲ or ▼ key to select from Unipolar or Bipolar. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

4.12.3 Analog Output 3 Volt limit

In some instances it may be desirable to limit the maximum voltage of the Analog Output 3, for example, when driving a magnet power supply.

The next analog output setup screen appears as a prompt for configuring the voltage limit.



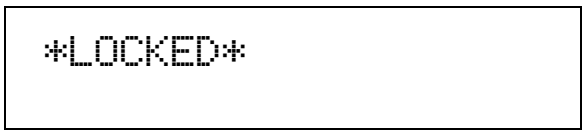
Use the ▲ or ▼ key to select from 1 volt through 10 volts. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

4.13 LOCKING THE KEYPAD

The keypad lock feature prevents accidental changes to parameter values. When the keypad is locked all parameter values may be viewed but none may be changed from the front panel.

A 3-digit code must be used to lock and unlock the keypad. The factory default code is **123** and it can only be changed using a computer interface. If the instrument parameters are set to default values, the code is reset to the factory default. The instrument parameters cannot be reset to default values from the front panel when the keypad is locked.

The following message will appear on the display if the user attempts to change a locked parameter.



NOTE: The computer interface has a remote operation mode that may be mistaken for a locked keypad. If the Remote LED annunciator is on, press the **Local** key to regain local control of the instrument.

To lock the instrument keypad *press and hold* the **Enter** key for 5 seconds. The following screen appears as a prompt for the 3-digit lock code.

Use the data entry keys to enter the 3-digit lock code (default 123). The instrument returns to the normal display with the keypad locked.

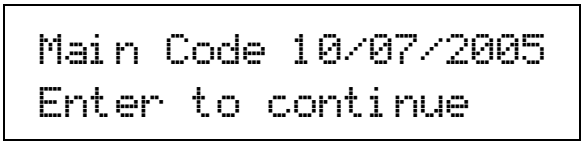
To unlock the instrument keypad *press and hold* the **Enter** key for 5 seconds. The following screen appears as a prompt for the 3-digit lock code.

Use the data entry keys to enter the 3-digit lock code (default 123). The instrument returns to the normal display with the keypad unlocked.

4.14 DEFAULT PARAMETER VALUES

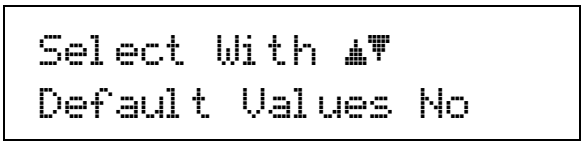
It is sometimes desirable to reset instrument parameters to their default values. This data is stored in EEPROM memory. Instrument calibration is not affected by this operation. The firmware version date is also displayed during this sequence.

To reset the EEPROM memory or view the firmware revision dates *press and hold* the **Escape** key for 5 seconds. The following screen appears to show the firmware revision date.



Press **Enter** to continue to the next setting screen. Press **Escape** to return to the normal display.

The next screen appears as a prompt for returning the instrument parameters to default values. Default parameter values are listed in Table 4-1.



Use the ⩙ or ⩛ keys to select Yes for default values and No to continue without changing the parameter values. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

Table 4-1. Default Parameter Values

Alarm and Relay	**Filter**
Alarm ..... Off	DC Resolution 5
Alarm Mode ..... Magnitude	RMS Measurement Band ..... Wide
Alarm Trigger ..... Outside	**Keypad Locking**
Alarm Audible ..... On	Mode ..... Unlocked
Relay 1 ..... Manual Off	Lock Code 123
Relay 2 ..... Manual Off	**Measurement**
Analog Output	Measurement Mode ..... DC
Analog Output 3 Mode ..... Off	Autorange ..... On
Analog Output 3 Polarity ..... Bipolar	Field Compensation ..... On
Analog Output 3 Limit 10V	Temperature Compensation ..... On
Analog Output 3 Manual Out ..... 0 *	Peak Mode ..... Pulse
Computer Interface	Peak Display ..... Both
Baud 9600	Max Hold ..... Off
IEEE Address 12	Max Mode ..... Magnitude
IEEE Terminators ..... CR/LF	Max Display ..... Both
Display	Relative ..... Off
Bottom Line ..... Temp/Freq	**Remote/Local**
Brightness 75%	Remote/Local ..... Local *
Field Units ..... Gauss	
Temperature Units ..... °C	

* Indicates value is also initialized on power up.

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CHAPTER 5

ADVANCED OPERATION

5.0 GENERAL

This chapter provides information on advanced operations for the Model 455 DSP Gaussmeter.

5.1 PROBE MANAGEMENT

The Model 455 has several capabilities that allow the best possible measurements with Lake Shore probes. These firmware-based features work in tandem with probe calibration and programming to ensure accurate, repeatable measurements and ease of setup. Many of the features require probe characteristics that are stored in non-volatile memory located in the probe connector during calibration.

5.1.1 Clear Probe Zero Calibration

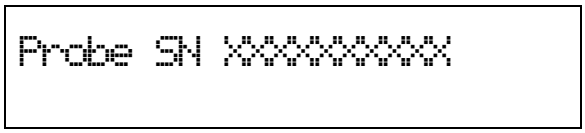
In some instances it may be useful to clear the results of the zero probe function. This could be of value if the probe was zeroed improperly or if the user suspected that the probe was damaged. By clearing the results of the zero probe function, the instrument is returned to a known calibrated state.

To clear the results of the zero probe function, *press and hold* the **Zero Probe** key for approximately 4 seconds. The screen appears as a prompt for clearing the zero probe function.

Use the ▲ or ▼ key to select Yes or No. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the selection and return to the normal display.

5.1.2 Probe Serial Number

The serial number of the probe presently attached can be viewed from the display of the Model 455. This feature can also be used to check the programming of extension cables. To view the serial number, press the **Probe** key. The following screen will appear for approximately 6 seconds.



Where XXXXXXXXXX, is the serial number of the attached probe, up to 10 digits in length.

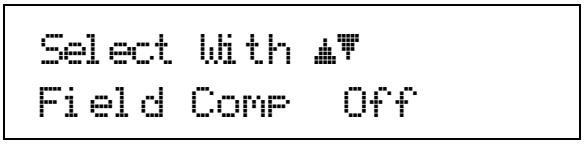
5.1.3 Field and Temperature Compensation

NOTE: Unless there is a specific reason, Lake Shore strongly advises customers *not* to turn field and temperature compensation off; it may reduce reading accuracy substantially.

To improve accuracy, all Lake Shore probes have a magnetic field compensation table stored in a PROM. Turning Field Compensation OFF causes the Model 455 to ignore this table and calculate the field based on a nominal probe sensitivity.

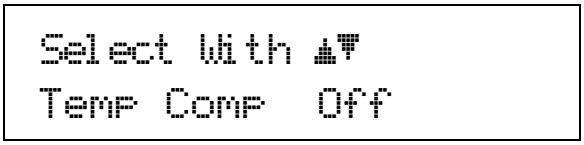
Some probes also feature temperature compensation. Turning Temperature Compensation OFF causes the Model 455 to ignore this data.

To configure the Field Compensation setting, press the Probe key and wait until the Probe Serial number display disappears and the following screen appears as a prompt for field compensation.



Use the ▲ or ▼ key to select Off or On. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the selection and return to the normal display.

The next probe setting screen appears as a prompt for changing the temperature compensation setting.



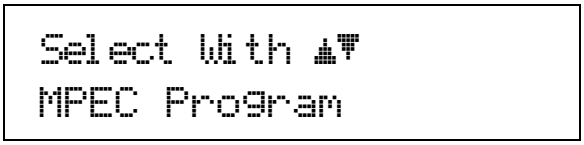
Use the ▲ or ▼ key to select Off or On. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the selection and return to the normal display. If the probe does not include temperature compensation, this setting is ignored.

5.1.4 Extension Cable

The complex nature of Hall-effect measurements makes it necessary to match extension cables to the probe when longer cables are needed. Keeping probes and their extensions from getting mixed up can become a problem when more than one probe is in use. The Model 455 alleviates some of the difficulty by allowing users to match probes to extensions in the field. Stored information can be viewed on the front panel and read over computer interface to ensure proper mating.

NOTE: Calibrated probe and extension cable pairs may be purchased from Lake Shore and are recommended for the best accuracy. Extension cables with no calibration may also be used. The Model 455 can then be used to match a probe to the un-calibrated extension cable.

To match a probe with an extension cable, verify that the probe is connected to the instrument. To begin the matching process, *press and hold* the **Probe** key for approximately 4 seconds. The following screen appears as a prompt for selecting the programming method.

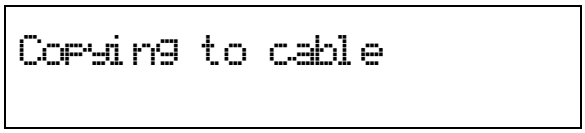


Use the ▲ or ▼ key to select from MPEC program (extension cables) or MCBL Program (User programmable cables, refer to Section 5.2.1). Press **Enter** to accept the new selection and continue the matching process. Press **Escape** to cancel the selection and return to the normal display.

The next probe matching screen appears as a prompt to begin the copying process.

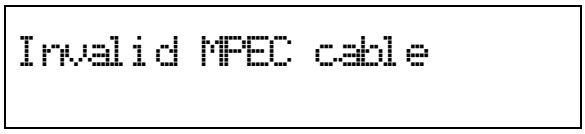
Visually verify that a valid HMPEC cable is attached to the Model 455. Press **Enter** to copy the probe characteristics to the memory of the extension cable. Press **Escape** to cancel the process and return to the normal display.

If a valid HMPEC cable is attached, and **Enter** is pressed, the following message will appear while the extension cable is programmed with the probe characteristics.



The process will be complete and the display will return to the normal display when this message disappears.

If an invalid HMPEC cable is attached, and the probe matching process is attempted, the following message will appear for approximately 5 seconds.



If this occurs, verify that the cable is properly connected. This message will also appear if an attempt is made to copy to a previously calibrated Lake Shore probe.

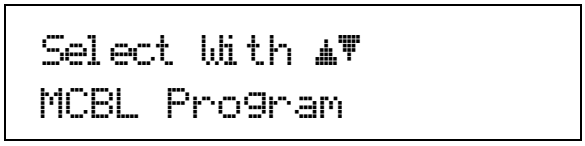
5.2 HALL GENERATOR

The Model 455 will operate with a discrete Hall generator when a suitable probe is not available. Users can program nominal sensitivity and serial number into a blank connector (HMCBL-XX, ordered separately) to provide all gaussmeter functions except field and temperature compensation. Note that, unlike a fully calibrated probe, the accuracy is affected by the Hall sensor linearity. If the HMCBL cable is not loaded with sensitivity information (or a 0.0 sensitivity is mistakenly entered), the Model 455 reverts to resistance measurement, otherwise the instrument will use the previously loaded sensitivity.

5.2.1 User Programmable Cable

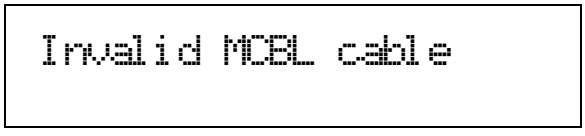
If the Model 455 detects the presence of a HMCBL cable with no sensitivity information (a new, blank cable), the instrument will display a message indicating "Invalid Probe." Press the **Enter** button to clear the message. The instrument will jump directly to the probe setup screens beginning with the probe serial number entry screen. If the instrument is already displaying a reading, the probe information may be changed.

To configure the HMCBL cable, *press and hold* the **Probe** key for approximately 4 seconds. The following screen appears as a prompt for selecting the programming method.



Use the ▲ or ▼ key to select the MCBL Program (user programmable cables). Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the selection and return to the normal display.

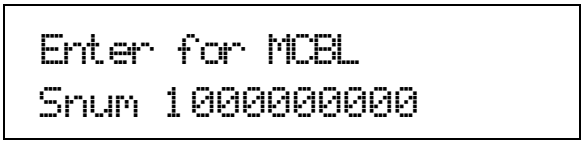
If an invalid HMCBL cable is attached (for instance, a fully calibrated Lake Shore probe), and the MCBL program is attempted, the following message will appear for approximately 5 seconds.



If this occurs, verify that the cable is properly connected. If the "invalid" message continues, either replace the cable with a proper HMCBL cable or contact Lake Shore Service.

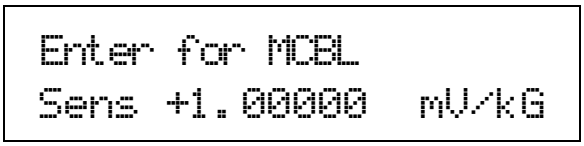
User Programmable Cable (Continued)

If a valid HMCBL cable is attached, the next MCBL Program screen appears as a prompt for serial number entry.



Use the number entry keys to enter the numeric serial number, up to 10 digits. Press **Enter** to accept the new value and continue to the next setting screen. If desired, press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

The next MCBL program screen appears as a prompt for entering the nominal sensitivity in mV/kG. This sensitivity is based on a 100 mA Hall current.



Use the data entry keys to enter the nominal sensitivity value from one of the following ranges: between 0.550 and 1.100 mV/kG; between 5.500 and 11.000 mV/kG; and between 550 and 1100 mV/kG. Press **Enter** to accept the new value and return to the normal display. If desired, press **Escape** to restart the setting sequence and enter a new value. Press **Escape** again to cancel the sequence and return to the normal display.

The Model 455 will adjust the available ranges based on the values entered for the current and sensitivity.

NOTE: Using a sensitivity outside the above ranges may cause reduced performance. Values near, but lower than the "55" minimum will reduce resolution. Values near, but above the "11" maximum may cause an instrument overload "OL" condition before full scale range is reached. Hence, using Hall generators with sensitivities outside the above-indicated ranges is discouraged.

All of the above entries will be stored in the HMCBL cable PROM (located in the connector). Thus, any time the cable/Hall generator combination is used, the Model 455 will recognize the stored parameters, and operation may proceed. The HMCBL cables may be reprogrammed for other Hall generators as needed.

A Hall generator can be connected directly to the Model 455 without using an HMCBL cable. Probe parameters can be configured as stated above but the settings will be lost if power is cycled.

5.2.2 Ohms Measurement Mode

The Model 455 may be configured to make a 4-lead resistive measurement. If the sensitivity of the probe is set to 0, the instrument will read in ohms. Instrument features are limited in this mode. The following ranges are available in this mode: 350 μΩ, 3.5 mΩ, 35 mΩ, 350 mΩ, and 3.5 Ω.

CHAPTER 6

COMPUTER INTERFACE OPERATION

6.0 GENERAL

This chapter provides operational instructions for the computer interface for the Lake Shore Model 455 Gaussmeter. Either of the two computer interfaces provided with the Model 455 permit remote operation. The first is the IEEE-488 Interface described in Section 6.1. The second is the Serial Interface described in Section 6.2. The two interfaces share a common set of commands detailed in Section 6.3. Only one of the interfaces can be used at a time.

6.1 IEEE-488 INTERFACE

The IEEE-488 Interface is an instrumentation bus with hardware and programming standards that simplify instrument interfacing. The Model 455 IEEE-488 Interface complies with the IEEE-488.2-1987 standard and incorporates its functional, electrical, and mechanical specifications unless otherwise specified in this manual.

All instruments on the interface bus perform one or more of the interface functions of TALKER, LISTENER, or BUS CONTROLLER. A TALKER transmits data onto the bus to other devices. A LISTENER receives data from other devices through the bus. The BUS CONTROLLER designates to the devices on the bus which function to perform. The Model 455 performs the functions of TALKER and LISTENER but cannot be a BUS CONTROLLER. The BUS CONTROLLER is the digital computer which tells the Model 455 which functions to perform.

Below are Model 455 IEEE-488 interface capabilities:

- **SH1:** Source handshake capability.
- **RL1:** Complete remote/local capability.
- **DC1:** Full device clear capability.
- **DT0:** No device trigger capability.
- **C0:** No system controller capability.
- **T5:** Basic TALKER, serial poll capability, talk only, unaddressed to talk if addressed to listen.
- **L4:** Basic LISTENER, unaddressed to listen if addressed to talk.
- **SR1:** Service request capability.
- **AH1:** Acceptor handshake capability.
- **PP0:** No parallel poll capability.
- **E1:** Open collector electronics.

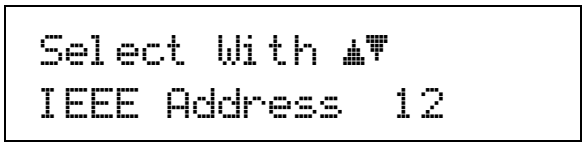
Instruments are connected to the IEEE-488 bus by a 24-conductor connector cable as specified by the standard. Refer to Section 8.11.2. Cables can be purchased from Lake Shore or other electronic suppliers. A connector extender (Model 4005) is required to use the IEEE-488 Interface and the Auxiliary connector at the same time.

Cable lengths are limited to 2 meters for each device and 20 meters for the entire bus. The Model 455 can drive a bus with up to 10 loads. If more instruments or cable length is required, a bus expander must be used.

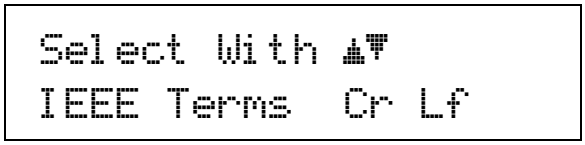
6.1.1 Changing IEEE-488 Interface Parameters

Two interface parameters. address and terminators, must be set from the front panel before communication with the instrument can be established. Other interface parameters can be set via the interface using the device specific commands provided in Section 6.3.

To set the IEEE-488 parameters, press the **Interface** key and press **Enter** to skip past Serial Interface Baud Rate. The following computer interface screen appears as a prompt for the IEEE-488 address.



Use the ▲ or ▼ key to select an address between 1 and 30. The default is twelve. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display. The next interface screen appears as a prompt for the IEEE-488 terminators.



Use the ▲ or ▼ key to select one of the following terminators: CR/LF, LF/CR, LF, and EOI. The default is Cr Lf. Press **Enter** to accept the new selection and return to the normal display. Press **Escape** to cancel the new selection and return to the normal display.

6.1.2 Remote/Local Operation

Normal operations from the keypad are referred to as 'Local' operations. The Model 455 can also be configured for 'Remote' operations via the IEEE-488 interface or the **Local** key. The **Local** key will toggle between 'Remote' and 'Local' operations. During 'Remote' operations, the Remote LED annunciator will light and operations from the keypad will be disabled.

6.1.3 IEEE-488 Command Structure

The Model 455 supports several command types. These commands are divided into three groups.

1. **Bus Control** – Refer to Section 6.1.3.1.
   a. Universal
      (1) Uniline
      (2) Multiline
   b. Addressed Bus Control
2. **Common** – Refer to Section 6.1.3.2.
3. **Device Specific** – Refer to Section 6.1.3.3.
4. **Message Strings** – Refer to Section 6.1.3.4.

6.1.3.1 Bus Control Commands

A Universal Command addresses all devices on the bus. Universal Commands include Uniline and Multiline Commands. A Uniline Command (Message) asserts only a single signal line. The Model 455 recognizes two of these messages from the BUS CONTROLLER: **Remote (REN)** and **Interface Clear (IFC)**. The Model 455 sends one Uniline Command: **Service Request (SRQ)**.

REN (Remote) – Puts the Model 455 into remote mode.

IFC (Interface Clear) – Stops current operation on the bus.

SRQ (Service Request) – Tells the bus controller that the Model 455 needs interface service, see Section 6.1.4.

A Multiline Command asserts a group of signal lines. All devices equipped to implement such commands do so simultaneously upon command transmission. These commands transmit with the Attention (ATN) line asserted low. The Model 455 recognizes two Multiline commands:

LLO (Local Lockout) – Prevents the use of instrument front panel controls.

DCL (Device Clear) – Clears Model 455 interface activity and puts it into a bus idle state.

Finally, Addressed Bus Control Commands are Multiline commands that must include the Model 455 listen address before the instrument responds. Only the addressed device responds to these commands. The Model 455 recognizes three of the Addressed Bus Control Commands:

SDC (Selective Device Clear) – The SDC command performs essentially the same function as the DCL command except that only the addressed device responds.

GTL (Go To Local) – The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger) – The GET command is used to trigger a device to have its operation started either individually or as part of a group of devices.

SPE (Serial Poll Enable) and **SPD (Serial Poll Disable)** – Serial polling accesses the Service Request Status Byte Register. This status register contains important operational information from the unit requesting service. The SPD command ends the polling sequence.

6.1.3.2 Common Commands

Common Commands are addressed commands, which create commonality between instruments on the bus. All instruments that comply with the IEEE-488 1987 standard share these commands and their format. Common commands all begin with an asterisk. They generally relate to "bus" and "instrument" status and identification. Common query commands end with a question mark (?). Model 455 common commands are detailed in Section 6.3 and summarized in Table 6-9.

6.1.3.3 Device Specific Commands

Device specific commands are addressed commands. The Model 455 supports a variety of device specific commands to program instruments remotely from a digital computer and to transfer measurements to the computer. Most device specific commands perform functions also performed from the front panel. Model 455 device specific commands are detailed in Section 6.3 and summarized in Table 6-9.

6.1.3.4 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings: commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings or queries can be chained together in one communication but they must be separated by a semi-colon (;). The total communication string must not exceed 255 characters in length.

A command string is issued by the computer and instructs the instrument to either perform a function or change a parameter setting. When a command is issued, the computer is acting as 'talker' and the instrument as 'listener'. The format is:

<command mnemonic><space><parameter data><terminators>.

Command mnemonics and parameter data necessary for each one is described in Section 6.3. Terminators must be sent with every message string.

A query string is issued by the computer and instructs the instrument which response to send. Queries are issued similar to commands with the computer acting as 'talker' and the instrument as 'listener'. The query format is:

<query mnemonic><?><space><parameter data><terminators>.

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Section 6.3. Terminators must be sent with every message string. Issuing a query does not initiate a response from the instrument.

A response string is sent by the instrument only when it is addressed as a 'talker' and the computer becomes the 'listener'. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Section 6.3.

6.1.4 Status System

6.1.4.1 Overview

The Model 455 implements a status system compliant to the IEEE 488.2 – 1992 standard. The status system provides a method of recording and reporting instrument information and is typically used to control the Service Request (SRQ) interrupt line. A diagram of the status system is shown in Figure 6-1. The status system is made up of register sets, the Status Byte register, and the Service Request Enable register. Each register set consists of three types of registers, condition, event, and enable.

6.1.4.1.0 Condition Registers

Each register set (except the Standard Event Register set) includes a condition register as shown in Figure 6-1. The condition register constantly monitors the instrument status. The data bits are real-time and are not latched or buffered. The register is read-only.

6.1.4.1.1 Event Registers

Each register set includes an event register as shown in Figure 6-1. Bits in the event register correspond to various system events and latch when the event occurs. When an event bit is set, subsequent events corresponding to that bit are ignored. Set bits remain latched until the register is cleared by a query command (such as *ESR?) or a *CLS command. The register is read-only.

6.1.4.1.2 Enable Registers

Each register set includes an enable register as shown in Figure 6-1. An enable register determines which bits in the corresponding event register will set the summary bit for the register set in the Status Byte. The user may write to or read from an enable register. Each event register bit is logically ANDed to the corresponding enable bit of the enable register. When an enable register bit is set by the user, and the corresponding bit is set in the event register, the output (summary) of the register will be set, which in turn sets the summary bit of the Status Byte register.

6.1.4.1.3 Status Byte Register

The Status Byte register, typically referred to as simply the Status Byte, is a non-latching, read-only register that contains all of the summary bits from the register sets. The status of the summary bits are controlled from the register sets as explained above. The Status Byte also contains the Request for Service (RQS)/Master Summary Status (MSS) bit. This bit is used to control the Service Request hardware line on the bus and to report if any of the summary bits are set via the *STB? command. The status of the RQS/MSS bit is controlled by the summary bits and the Service Request Enable Register.

6.1.4.1.4 Service Request Enable Register

The Service Request Enable Register determines which summary bits in the Status Byte will set the RQS/MSS bit of the Status Byte. The user may write to or read from the Service Request Enable Register. Each Status Byte summary bit is logically ANDed to the corresponding enable bit of the Service Request Enable Register. When a Service Request Enable Register bit is set by the user, and the corresponding summary bit is set in the Status Byte, the RQS/MSS bit of the Status Byte will be set, which in turn sets the Service Request hardware line on the bus.

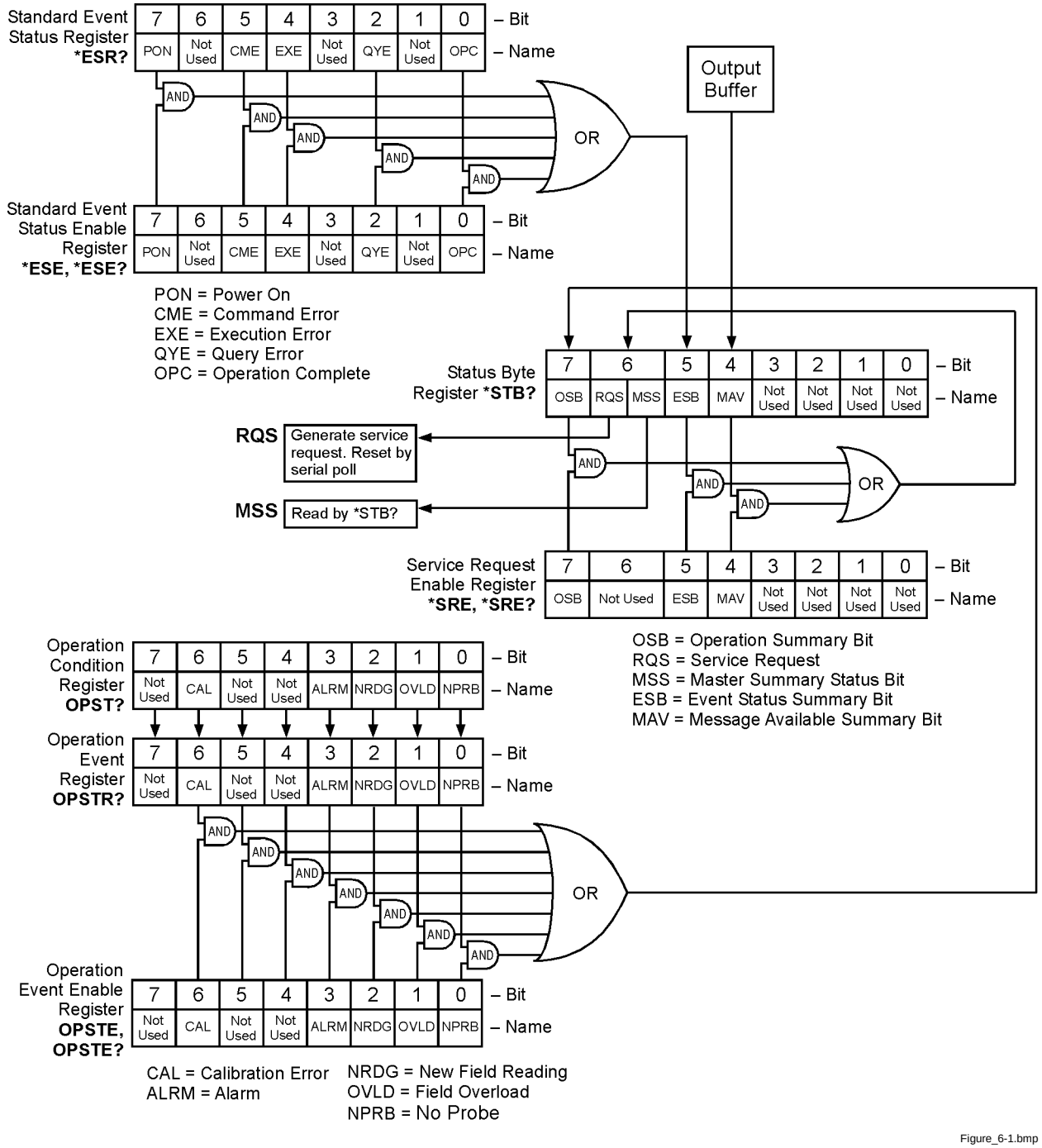

Standard Event Status Register *ESR?
7 6 5 4 3 2 1 0 – Bit
PON Not Used CME EXE Not Used QYE Not Used OPC – Name
AND
OR
Output Buffer
Standard Event Status Enable Register *ESE, *ESE?
PON = Power On
CME = Command Error
EXE = Execution Error
QYE = Query Error
OPC = Operation Complete
Status Byte Register *STB?
OSB RQS MSS ESB MAV Not Used Not Used Not Used Not Used – Name
RQS
Generate service request. Reset by serial poll
MSS
Read by *STB?
Service Request Enable Register *SRE, *SRE?
OSB Not Used ESB MAV Not Used Not Used Not Used Not Used – Name
OSB = Operation Summary Bit
RQS = Service Request
MSS = Master Summary Status Bit
ESB = Event Status Summary Bit
MAV = Message Available Summary Bit
Operation Condition Register OPST?
Not Used CAL Not Used Not Used ALRM NRDG OVLD NPRB – Name
Operation Event Register OPSTR?
Operation Event Enable Register OPSTE, OPSTE?
CAL = Calibration Error
ALRM = Alarm
NRDG = New Field Reading
OVLD = Field Overload
NPRB = No Probe

Figure_6-1.bmp

Figure 6-1. Model 455 Status System

6.1.4.1.5 Reading Registers

Any register in the status system may be read using the appropriate query command. Some registers clear when read, others do not. Refer to Section 6.1.4.1.7. The response to a query will be a decimal value which corresponds to the binary-weighted sum of all bits in the register, refer to Table 6-1. The actual query commands are described later in this section.

Table 6-1. Binary Weighting of an 8-Bit Register

Position	B7	B6	B5	B4	B3	B2	B1	B0
Decimal	128	64	32	16	8	4	2	1
Weighting	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Example: If bits 0, 2, and 4 are set, a query of the register will return a decimal value of 21 (1+4+16).

6.1.4.1.6 Programming Registers

The only registers that may be programmed by the user are the enable registers. All other registers in the status system are read-only registers. To program an enable register send a decimal value which corresponds to the desired binary-weighted sum of all bits in the register, refer to Table 6-1. The actual commands are described later in this section.

6.1.4.1.7 Clearing Registers

The methods to clear each register are detailed in Table 6-2.

Table 6-2. Register Clear Methods

Register	Method	Example
Condition Registers	None – registers are not latched	–
Event Registers Standard Event Status Register Operation Event Register	Query the event register.	*ESR? (clears Standard Event Status register)
	Send *CLS	*CLS (clears both registers)
	Power on instrument	–
Enable Registers: Standard Event Status Enable Register Operation Event Enable Register Service Request Enable Register	Write 0 to the enable register.	*ESE 0 (clears Standard Event Status Enable register)
	Power on instrument	–
Status Byte	There are no commands that directly clear the Status Byte as the bits are non-latching. To clear individual summary bits, clear the event register that corresponds to the summary bit. Sending *CLS will clear all event registers which in turn clears the status byte.	If bit 5 (ESB) of the Status Byte is set, send *ESR? to read the Standard Event Status Register and bit 5 will clear.
	Power on instrument	–

6.1.4.2 Status Register Sets

As shown in Figure 6-1, there are two register sets in the status system of the Model 455: Standard Event Status Register and Operation Event Register.

6.1.4.2.1 Standard Event Status Register Set

The Standard Event Status Register reports the following interface related instrument events: power on detected, command syntax errors, command execution errors, query errors, operation complete. Any or all of these events may be reported in the standard event summary bit through the enable register, see Figure 6-2. The Standard Event Status Enable command (*ESE) programs the enable register and the query command (*ESE?) reads it. *ESR? reads and clears the Standard Event Status Register. The used bits of the Standard Event Register are described as follows:

Power On (PON), Bit (7) – This bit is set to indicate an instrument off-on transition.

Command Error (CME), Bit (5) – This bit is set if a command error has been detected since the last reading. This means that the instrument could not interpret the command due to a syntax error, an unrecognized header, unrecognized terminators, or an unsupported command.

Execution Error (EXE), Bit (4) – This bit is set if an execution error has been detected. This occurs when the instrument is instructed to do something not within its capabilities.

Query Error (QYE), Bit (2) – This bit indicated a query error. It occurs rarely and involves loss of data because the output queue is full.

Operation Complete (OPC), Bit (0) – When *OPC is sent, this bit will be set when the instrument has completed all pending operations. The operation of this bit is not related to the *OPC? command which is a separate interface feature. Refer to Section 6.1.4.3.6 for more information.

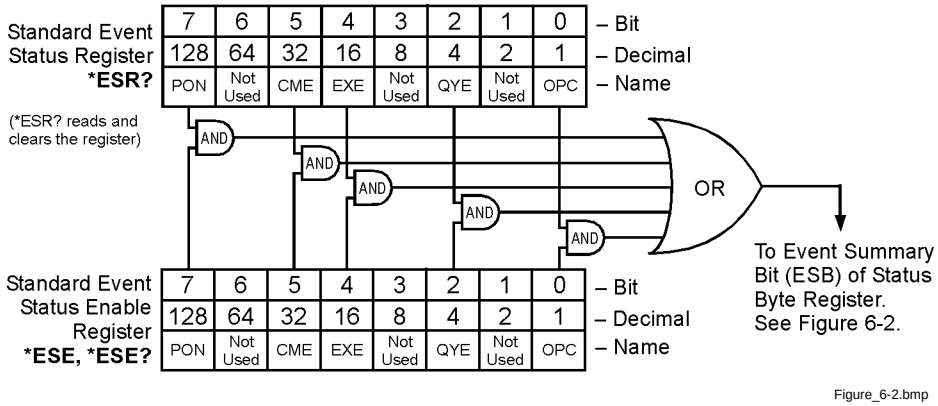

Standard Event Status Register *ESR?
7 6 5 4 3 2 1 0 – Bit
128 64 32 16 8 4 2 1 – Decimal
PON Not Used CME EXE Not Used QYE Not Used OPC – Name
(*ESR? reads and clears the register)
AND
OR
To Event Summary Bit (ESB) of Status Byte Register. See Figure 6-2.
Standard Event Status Enable Register *ESE, *ESE?
7 6 5 4 3 2 1 0 – Bit
128 64 32 16 8 4 2 1 – Decimal
PON Not Used CME EXE Not Used QYE Not Used OPC – Name
Figure_6-2.bmp

Figure 6-2. Standard Event Status Register

6.1.4.2.2 Operation Event Register Set

The Operation Event Register reports the following interface related instrument events: ramp done, datalog done, alarm, new reading, field overload, no probe. Any or all of these events may be reported in the operation event summary bit through the enable register, see Figure 6-3. The Operation Event Enable command (OPSTE) programs the enable register and the query command (OPSTE?) reads it. OPSTR? reads and clears the Operation Event Register. OPST? reads the Operation Condition register. The used bits of the Operation Event Register are described as follows:

Calibration Error (CAL), Bit (6) – This bit is set if the instrument is not calibrated or the calibration data has been corrupted.

Alarm, Bit (3) – This bit is set when there is an alarm condition.

New Field Reading, Bit (2) – This bit is set when there is a new field reading.

Field Overload, Bit (1) – This bit is set when the field reading is in an overload condition.

No Probe, Bit (0) – This bit is set if the instrument is unable to detect a probe.

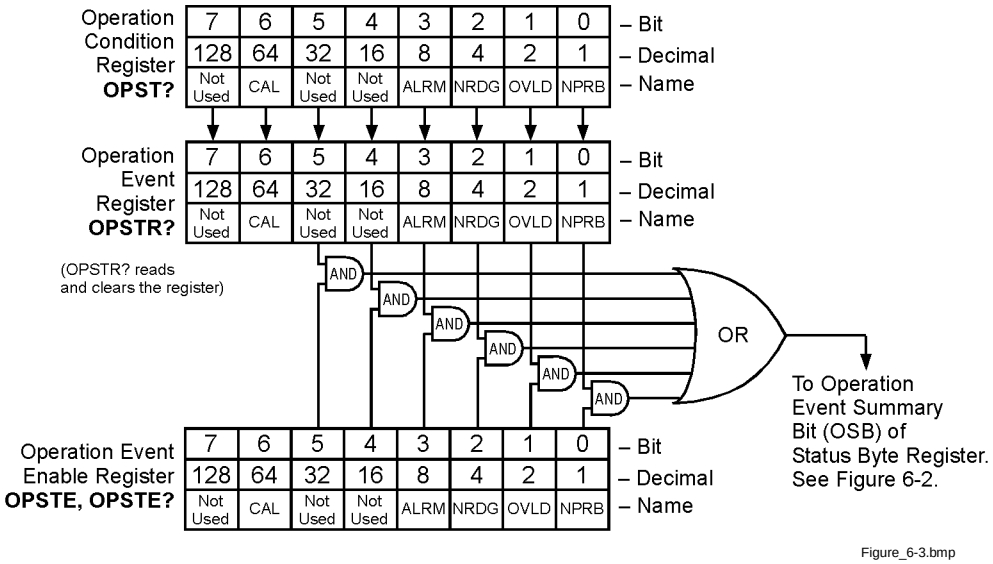

Operation Condition Register OPST?
Operation Event Register OPSTR?
(OPSTR? reads and clears the register)
Operation Event Enable Register OPSTE, OPSTE?
7 6 5 4 3 2 1 0 – Bit
128 64 32 16 8 4 2 1 – Decimal
Not Used CAL Not Used Not Used ALRM NRDG OVLD NPRB – Name
AND
OR
To Operation Event Summary Bit (OSB) of Status Byte Register. See Figure 6-2.
Figure_6-3.bmp

Figure 6-3. Operation Event Register

6.1.4.3 Status Byte and Service Request (SRQ)

As shown in Figure 6-1, the Status Byte Register receives the summary bits from the two status register sets and the message available summary bit from the output buffer. The status byte is used to generate a service request (SRQ). The selection of summary bits that will generate an SRQ is controlled by the Service Request Enable Register.

6.1.4.3.1 Status Byte Register

The summary messages from the event registers and output buffer set or clear the summary bits of the Status Byte Register, see Figure 6-4. These summary bits are not latched. Clearing an event register will clear the corresponding summary bit in the Status Byte Register. Reading all messages in the output buffer, including any pending queries, will clear the message available bit. The bits of the Status Byte Register are described as follows:

Operation Summary (OSB), Bit (7) – Set summary bit indicates that an enabled operation event has occurred.

Request Service (RQS)/Master Summary Status (MSS), Bit (6) – This bit is set when a summary bit and the summary bits corresponding enable bit in the Service Request Enable Register are set. Once set, the user may read and clear the bit in two different ways, which is why it is referred to as both the RQS and the MSS bit. When this bit goes from low to high, the Service Request hardware line on the bus is set, this is the RQS function of the bit. Refer to Section 6.1.4.3.3. In addition, the status of the bit may be read with the *STB? query which returns the binary weighted sum of all bits in the Status Byte, this is the MSS function of the bit.

Performing a serial poll will automatically clear the RQS function but not the MSS function. A *STB? will read the status of the MSS bit (along with all of the summary bits), but also will not clear it. To clear the MSS bit, either clear the event register that set the summary bit or disable the summary bit in the Service Request Enable Register.

Event Summary (ESB), Bit (5) – Set summary bit indicates that an enabled standard event has occurred.

Message Available (MAV), Bit (4) – Set summary bit indicates that a message is available in the output buffer.

Bit (3) – Not used.
Bit (2) – Not used.
Bit (1) – Not used.
Bit (0) – Not used.

6.1.4.3.2 Service Request Enable Register

The Service Request Enable Register is programmed by the user and determines which summary bits of the Status Byte may set bit 6 (RQS/MSS) to generate a Service Request. Enable bits are logically ANDed with the corresponding summary bits, see Figure 6-4. Whenever a summary bit is set by an event register and its corresponding enable bit is set by the user, bit 6 will set to generate a service request. The Service Request Enable command (*SRE) programs the Service Request Enable Register and the query command (*SRE?) reads it. Reading the Service Request Enable Register will not clear it. The register may be cleared by the user by sending *SRE 0.

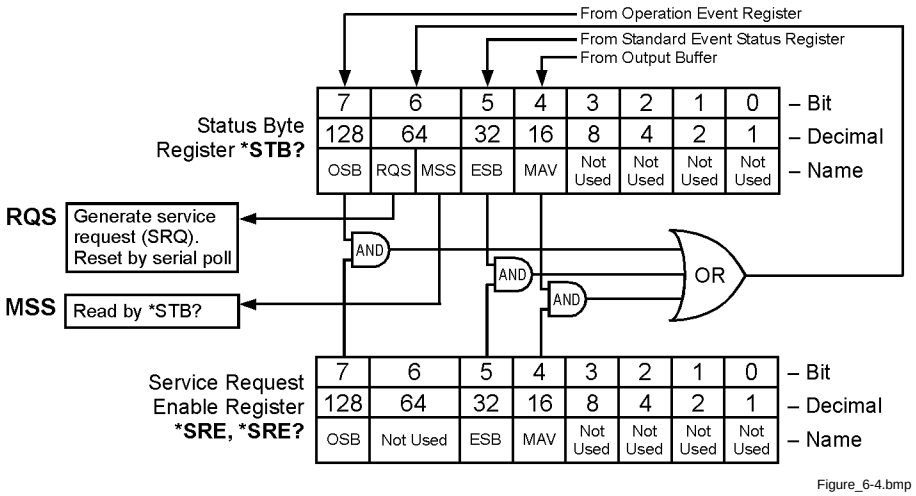

From Operation Event Register
From Standard Event Status Register
From Output Buffer
Status Byte Register *STB?
7 6 5 4 3 2 1 0 – Bit
128 64 32 16 8 4 2 1 – Decimal
OSB RQS MSS ESB MAV Not Used Not Used Not Used Not Used – Name
RQS
Generate service request (SRQ). Reset by serial poll
MSS
Read by *STB?
AND
AND
AND
OR
Service Request Enable Register *SRE, *SRE?
7 6 5 4 3 2 1 0 – Bit
128 64 32 16 8 4 2 1 – Decimal
OSB Not Used ESB MAV Not Used Not Used Not Used Not Used – Name
Figure_6-4.bmp

Figure 6-4. Status Byte Register and Service Request Enable Register

6.1.4.3.3 Using Service Request (SRQ) and Serial Poll

When a Status Byte summary bit (or MAV bit) is enabled by the Service Request Enable Register and goes from 0 to 1, bit 6 (RQS/MSS) of the status byte will be set. This will send a service request (SRQ) interrupt message to the bus controller. The user program may then direct the bus controller to serial Poll the instruments on the bus to identify which one requested service (the one with bit 6 set in its status byte).

Serial polling will automatically clear RQS of the Status Byte Register. This allows subsequent serial polls to monitor bit 6 for an SRQ occurrence generated by other event types. After a serial poll, the same event or any event that uses the same Status Byte summary bit, will not cause another SRQ unless the event register that caused the first SRQ has been cleared, typically by a query of the event register.

The serial poll does not clear MSS. The MSS bit stays set until all enabled Status Byte summary bits are cleared, typically by a query of the associated event register, refer to Section 6.1.4.3.4.

The programming example in Table 6-3 initiates an SRQ when a command error is detected by the instrument.

Table 6-3. Programming Example to Generate an SRQ

Command or Operation	Description
*ESR?	Read and clear the Standard Event Status Register.
*ESE 32	Enable the Command Error (CME) bit in the Standard Event Status Register
*SRE 32	Enable the Event Summary Bit (ESB) to set the RQS
*ABC	Send improper command to instrument to generate a command error
Monitor bus	Monitor the bus until the Service Request interrupt (SRQ) is sent.
Initiate Serial Poll	Serial Poll the bus to determine which instrument sent the interrupt and clear the RQS bit in the Status Byte.
*ESR?	Read and clear the Standard Event Status Register allowing an SRQ to be generated on another command error.

*6.1.4.3.4 Using Status Byte Query (*STB?)*

The Status Byte Query (*STB?) command is similar to a Serial Poll except it is processed like any other instrument command.. The *STB? command returns the same result as a Serial Poll except that the Status Byte bit 6 (RQS/MSS) is not cleared. In this case bit 6 is considered the MSS bit. Using the *STB? command does not clear any bits in the Status Byte Register.

6.1.4.3.5 Using the Message Available (MAV) bit

Status Byte summary bit 4 (MAV) indicates that data is available to read into your bus controller. This message may be used to synchronize information exchange with the bus controller. The bus controller can, for example, send a query command to the Model 455 and then wait for MAV to set. If the MAV bit has been enabled to initiate an SRQ, the user's program can direct the bus controller to look for the SRQ leaving the bus available for other use. The MAV bit will be clear whenever the output buffer is empty.

*6.1.4.3.6 Using Operation Complete (*OPC) and Operation Complete Query (*OPC?)*

The Operation Complete (*OPC) and Operation Complete Query (*OPC?) are both used to indicate when pending device operations complete. However, the commands operate with two distinct methods.

The *OPC command is used in conjunction with bit 0 (OPC) of the Standard Event Status Register. If *OPC is sent as the last command in a command sequence, bit 0 will be set when the instrument completes the operation that was initiated by the command sequence. Additional commands may be sent between the instrument and the bus controller while waiting for the initial pending operation to complete. A typical use of this function would be to enable the OPC bit to generate an SRQ and include the *OPC command when programming the instrument. The bus controller could then be instructed to look for an SRQ allowing additional communication with the instrument while the initial process executes.

The *OPC? query has no interaction with bit 0 (OPC) of the Standard Event Status Register. If the *OPC? query is sent at the end of a command sequence, the bus will be held until the instrument completes the operation that was initiated by the command sequence. Additional commands (except *RST) should not be sent until the operation is complete as erratic operation will occur. Once the sequence is complete a 1 will be placed in the output buffer. This function is typically used to signal a completed operation without monitoring the SRQ. It is also used when it is important to prevent any additional communication on the bus during a pending operation.

6.1.5 IEEE Interface Example Program

A Visual Basic program is included to illustrate the IEEE-488 communication functions of the instrument. Refer to Section 6.1.5.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 6-5. A description of program operation is provided in Section 6.1.5.3. While the hardware and software required to produce and implement this program is not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

6.1.5.1 IEEE-488 Interface Board Installation for Visual Basic Program

This procedure works for Plug and Play GPIB Hardware and Software for Windows 98/95. This example uses the AT-GPIB/TNT GPIB card.

1. Install the GPIB Plug and Play Software and Hardware using National Instruments instructions.
2. Verify that the following files have been installed to the Windows System folder:
   a. gpib-32.dll
   b. gpib.dll
   c. gpib32ft.dll

   Files b and c support any 16-bit Windows GPIB applications being used.
3. Locate the following files and make note of their location. These files will be used during the development process of a Visual Basic program.
   a. Niglobal.bas
   b. Vbib-32.bas

NOTE: If the files in Steps 2 and 3 are not installed on your computer, they may be copied from your National Instruments setup disks or they may be downloaded from www.ni.com.

4. Configure the GPIB by selecting the System icon in the Windows 98/95 Control Panel located under Settings on the Start Menu. Configure the GPIB Settings as shown in Figure 6-5. Configure the DEV12 Device Template as shown in Figure 6-6. Be sure to check the Readdress box.

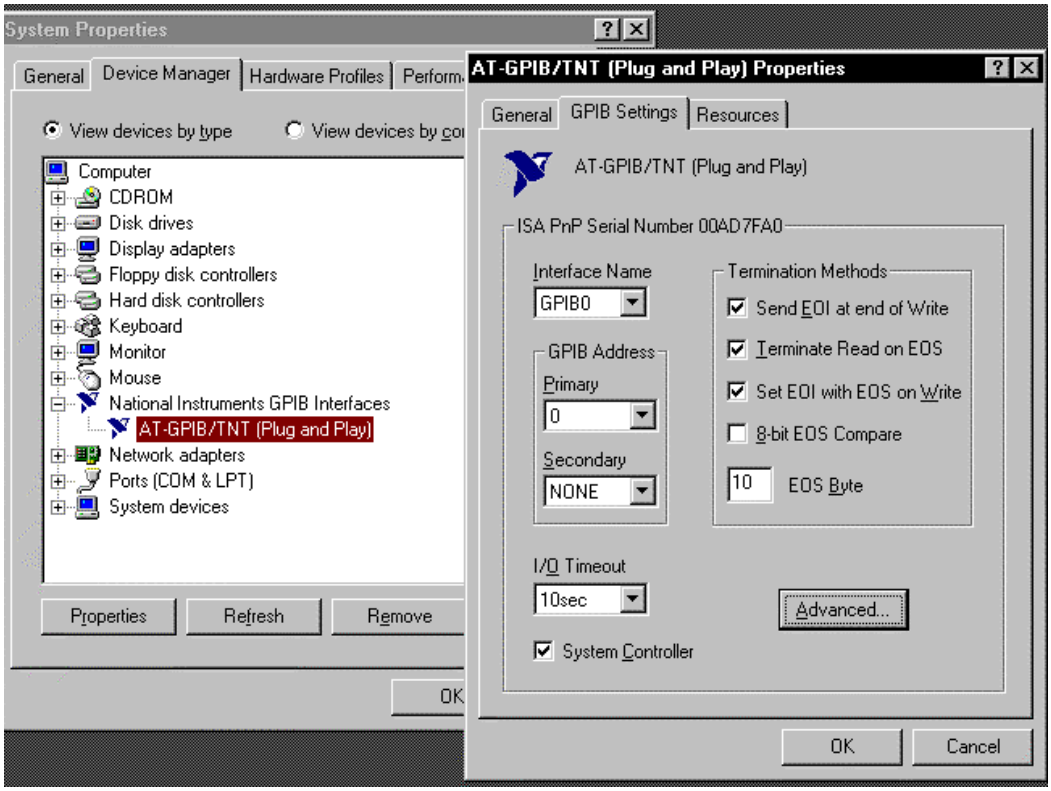


Figure 6-5. GPIB0 Setting Configuration

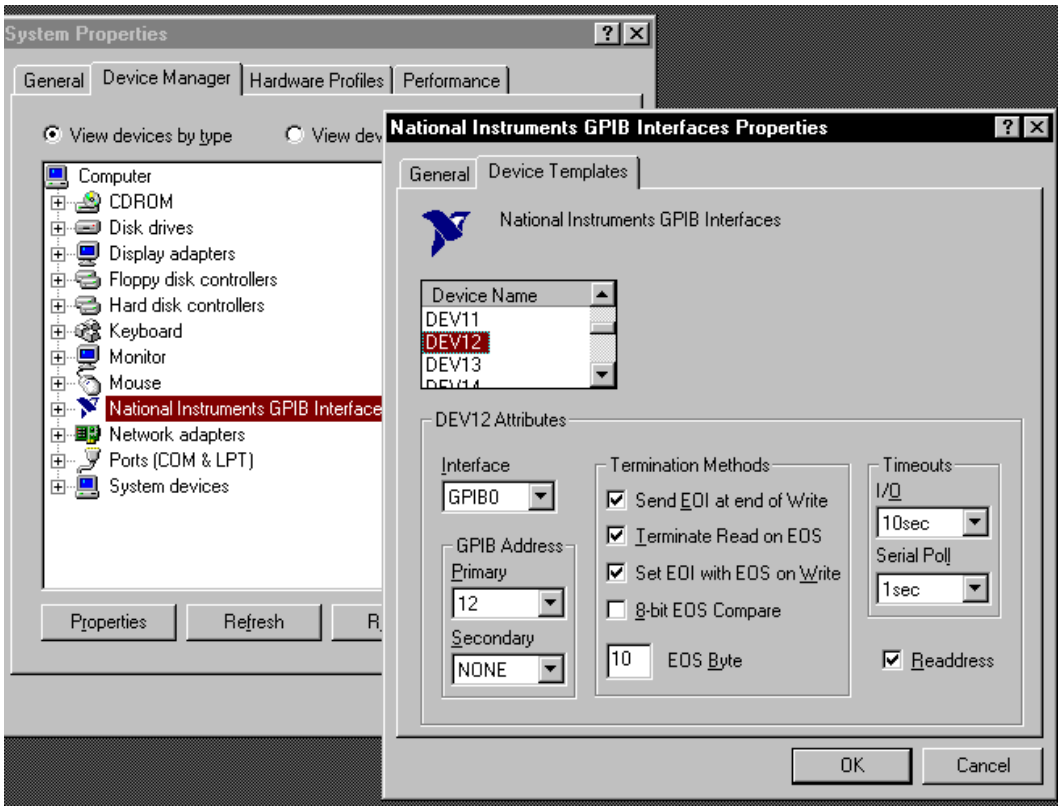
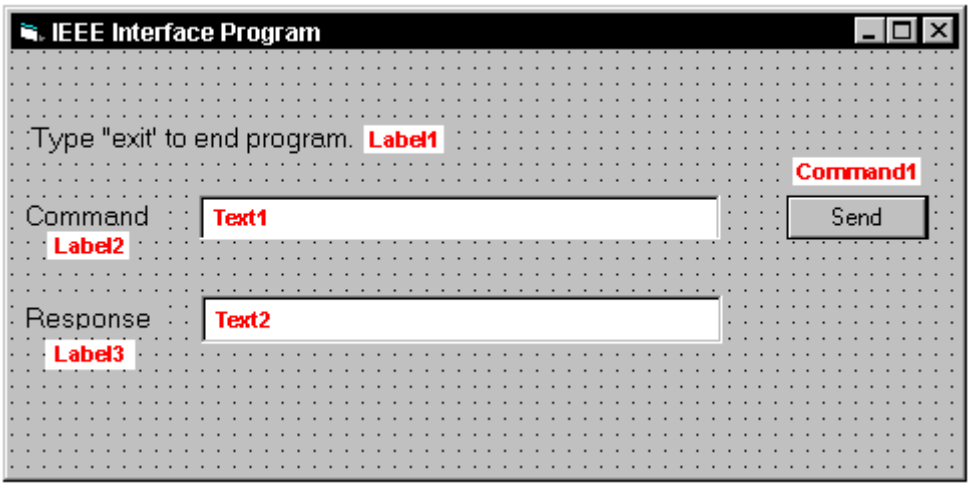


Figure 6-6. DEV 12 Device Template Configuration

6.1.5.2 Visual Basic IEEE-488 Interface Program Setup

This IEEE-488 interface program works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better. It assumes your IEEE-488 (GPIB) card is installed and operating correctly (refer to Section 6.1.5.1). Use the following procedure to develop the IEEE-488 Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, select Add Module, select the Existing tab, then navigate to the location on your computer to add the following files: Niglobal.bas and Vbib-32.bas.
5. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
6. On the View Menu, select Properties Window.
7. In the Properties window, use the dropdown list to select between the different controls of the current project.

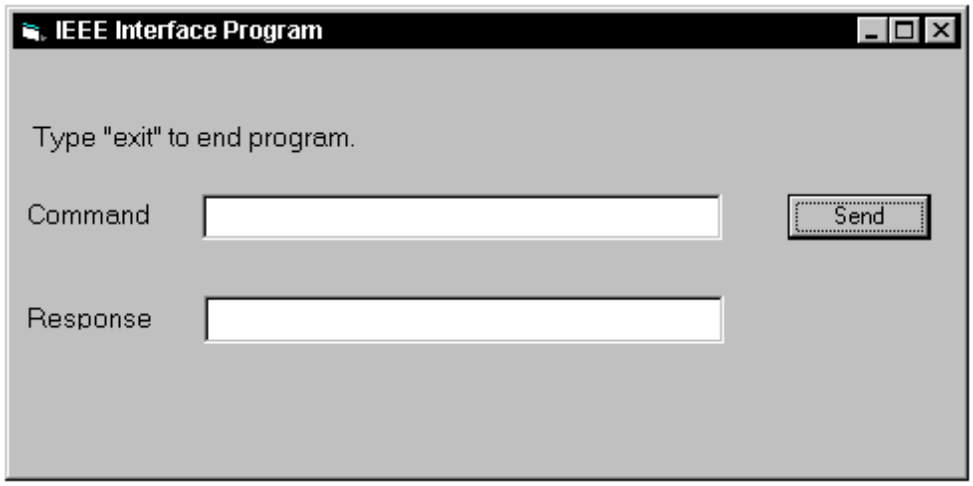


8. Set the properties of the controls as defined in Table 6-4.
9. Save the program.

Table 6-4. IEEE-488 Interface Program Control Properties

Current Name	Property	New Value
Label1	Name Caption	lblExitProgram Type "exit" to end program.
Label2	Name Caption	lblCommand Command
Label3	Name Caption	lblResponse Response
Text1	Name Text	txtCommand <blank>
Text2	Name Text	txtResponse <blank>
Command1	Name Caption Default	cmdSend Send True
Form1	Name Caption	frmIEEE IEEE Interface Program

10. Add code (provided in Table 6-5).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 6-5.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 6-5.
11. Save the program.
12. Run the program. The program should resemble the following.



13. Type in a command or query in the Command box as described in Section 6.1.5.5.
14. Press Enter or select the Send button with the mouse to send command.
15. Type Exit and press Enter to quit.

Table 6-5. Visual Basic IEEE-488 Interface Program

```
Public gSend As Boolean                                    'Global used for Send button state
Private Sub cmdSend_Click()                                'Routine to handle Send button press
   gSend = True                                            'Set Flag to True
End Sub
Private Sub Form_Load()                                    'Main code section
   Dim strReturn As String                                 'Used to return response
   Dim term As String                                      'Terminators
   Dim strCommand As String                                'Data string sent to instrument
   Dim intDevice As Integer                                'Device number used with IEEE

   frmIEEE.Show                                            'Show main window
   term = Chr(13) & Chr(10)                                'Terminators are <CR><LF>
   strReturn = ""                                          'Clear return string

   Call ibdev(0, 12, 0, T10s, 1, &H140A, intDevice)        'Initialize the IEEE device
   Call ibconfig(intDevice, ibcREADDR,1)                   'Setup Repeat Addressing
   Do
       Do                                                  'Wait loop
       DoEvents                                            'Give up processor to other events
       Loop Until gSend = True                             'Loop until Send button pressed
       gSend = False                                       'Set Flag as False

       strCommand = frmIEEE.txtCommand.Text                'Get Command
       strReturn = ""                                      'Clear response display

       strCommand = UCase(strCommand)                      'Set all characters to upper case
       If strCommand = "EXIT" Then                         'Get out on EXIT
           End
       End If

       Call ibwrt(intDevice, strCommand & term)            'Send command to instrument
       If (ibsta And EERR) Then                            'Check for IEEE errors
           'do error handling if needed                    'Handle errors here
       End If

       If InStr(strCommand, "?") <> 0 Then                 'Check to see if query
           strReturn = Space(100)                          'Build empty return buffer
           Call ibrd(intDevice, strReturn)                 'Read back response
           If (ibsta And EERR) Then                        'Check for IEEE errors
               'do error handling if needed                'Handle errors here
           End If

           If strReturn <> "" Then                         'Check if empty string
               strReturn = RTrim(strReturn)                'Remove extra spaces and Terminators
               Do While Right(strReturn, 1) = Chr(10) Or Right(strReturn, 1) = Chr(13)
                   strReturn = Left(strReturn, Len(strReturn) - 1)
               Loop
           Else
               strReturn = "No Response"                   'Send No Response
           End If

           frmIEEE.txtResponse.Text = strReturn            'Put response in text on main form
       End If
   Loop
End Sub
```

6.1.5.3 Program Operation

Once the example program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

ENTER COMMAND? ***IDN?**	Identification query. Instrument will return a string identifying itself.
RESPONSE: LSCI,MODEL455,1234567,02032003[term]	
ENTER COMMAND? **RDGFIELD?**	Field reading query. Instrument will return a string with the present field reading in the present units.
RESPONSE: +273.150E+00[term]	
ENTER COMMAND? **RANGE 1**	Field range command. Instrument will set to the lowest range. No response will be sent.
ENTER COMMAND? **RANGE?**	Field range query. Instrument will return a string with the present field range setting.
RESPONSE: 1[term]	
ENTER COMMAND? **RANGE 5;RANGE?**	Field range command followed by a query. Instrument will change to the highest range setting then return a string
RESPONSE: 5[term]	with the present setting.

The following are additional notes on using either IEEE-488 Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but are sent in response to a query. A leading "+" is not required but a leading "–" *is* required.

6.1.6 Troubleshooting

New Installation

1. Check instrument address.
2. Always send terminators.
3. Send entire message string at one time including terminators.
4. Send only one simple command at a time until communication is established.
5. Be sure to spell commands correctly and use proper syntax.
6. Attempt both 'Talk' and 'Listen' functions. If one works but not the other, the hardware connection is working, so look at syntax, terminators, and command format.
7. If only one message is received after resetting the interface, check the "repeat addressing" setting. It should be enabled.

Old Installation No Longer Working

8. Power instrument off then on again to see if it is a soft failure.
9. Power computer off then on again to see if the IEEE card is locked up.
10. Verify that the address has not been changed on the instrument during a memory reset.
11. Check all cable connections.

Intermittent Lockups

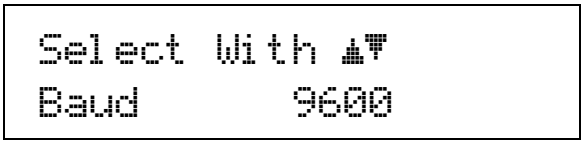
12. Check cable connections and length.
13. Increase delay between all commands to 50 ms to make sure instrument is not being over loaded.

6.2 SERIAL INTERFACE OVERVIEW

The serial interface used in the Model 455 is commonly referred to as an RS-232C interface. RS-232C is a standard of the Electronics Industries Association (EIA) that describes one of the most common interfaces between computers and electronic equipment. The RS-232C standard is quite flexible and allows many different configurations. However, any two devices claiming RS-232C compatibility cannot necessarily be plugged together without interface setup. The remainder of this paragraph briefly describes the key features of a serial interface that are supported by the instrument. A customer supplied computer with similarly configured interface port is required to enable communication.

6.2.1 Changing Baud Rate

To select the Serial Interface Baud Rate press the **Interface** key. The first computer interface screen appears as a prompt for Baud.



Use the ▲ or ▼ key to select 9600, 19200, 38400, or 57600 Baud. The default is 9600 Baud. Press **Enter** to accept the new selection and continue to the next setting screen. Press **Escape** to cancel the new selection and return to the normal display.

6.2.2 Physical Connection

The Model 455 has a 9 pin D-Subminiature plug on the rear panel for serial communication. The original RS-232C standard specifies 25 pins but both 9- and 25-pin connectors are commonly used in the computer industry. Many third party cables exist for connecting the instrument to computers with either 9- or 25-pin connectors. Section 8.11.1 gives the most common pin assignments for 9- and 25-pin connectors. Please note that not all pins or functions are supported by the Model 455.

The instrument serial connector is the plug half of a mating pair and must be matched with a socket on the cable. If a cable has the correct wiring configuration but also has a plug end, a "gender changer" can be used to mate two plug ends together.

The letters DTE near the interface connector stand for Data Terminal Equipment and indicate the pin connection of the directional pins such as transmit data (TD) and receive data (RD). Equipment with Data Communications Equipment (DCE) wiring can be connected to the instrument with a straight through cable. As an example, Pin 3 of the DTE connector holds the transmit line and Pin 3 of the DCE connector holds the receive line so the functions complement.

It is likely both pieces of equipment are wired in the DTE configuration. In this case Pin 3 on one DTE connector (used for transmit) must be wired to Pin 2 on the other (used for receive). Cables that swap the complementing lines are called null modem cables and must be used between two DTE wired devices. Null modem adapters are also available for use with straight through cables. Section 8.11.1 illustrates suggested cables that can be used between the instrument and common computers.

The instrument uses drivers to generate the transmission voltage levels required by the RS-232C standard. These voltages are considered safe under normal operating conditions because of their relatively low voltage and current limits. The drivers are designed to work with cables up to 50 feet in length.

6.2.3 Hardware Support

The Model 455 interface hardware supports the following features. Asynchronous timing is used for the individual bit data within a character. This timing requires start and stop bits as part of each character so the transmitter and receiver can resynchronized between each character. Half duplex transmission allows the instrument to be either a transmitter or a receiver of data but not at the same time. Communication speeds of 9600, 19200, 38400, or 57600 Baud are supported. The Baud rate is the only interface parameter that can be changed by the user.

Hardware handshaking is not supported by the instrument. Handshaking is often used to guarantee that data message strings do not collide and that no data is transmitted before the receiver is ready. In this instrument appropriate software timing substitutes for hardware handshaking. User programs must take full responsibility for flow control and timing as described in Section 6.2.6.

6.2.4 Character Format

A character is the smallest piece of information that can be transmitted by the interface. Each character is 10 bits long and contains data bits, bits for character timing and an error detection bit. The instrument uses 7 bits for data in the ASCII format. One start bit and one stop bit are necessary to synchronize consecutive characters. Parity is a method of error detection. One parity bit configured for odd parity is included in each character.

ASCII letter and number characters are used most often as character data. Punctuation characters are used as delimiters to separate different commands or pieces of data. Two special ASCII characters, carriage return (CR 0DH) and line feed (LF 0AH), are used to indicate the end of a message string.

Table 6-6. Serial Interface Specifications

Connector Type:	9-pin D-style connector plug
Connector Wiring:	DTE
Voltage Levels:	EIA RS-232C Specified
Transmission Distance:	50 feet maximum
Timing Format:	Asynchronous
Transmission Mode:	Half Duplex
Baud Rate:	9600, 19200, 38400, 57600
Handshake:	Software timing
Character Bits:	1 Start, 7 Data, 1 Parity, 1 Stop
Parity:	Odd
Terminators:	CR(0DH) LF(0AH)
Command Rate:	20 commands per second maximum

6.2.5 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings or queries can be chained together in one communication but they must be separated by a semi-colon (;) The total communication string must not exceed 255 characters in length.

A command string is issued by the computer and instructs the instrument to perform a function or change a parameter setting. The format is:

<command mnemonic><space><parameter data><terminators>.

Command mnemonics and parameter data necessary for each one is described in Section 6.3. Terminators must be sent with every message string.

Message Strings (Continued)

A query string is issued by the computer and instructs the instrument to send a response. The query format is:

<query mnemonic><?><space><parameter data><terminators>.

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Section 6.3. Terminators must be sent with every message string. The computer should expect a response very soon after a query is sent.

A response string is the instruments response or answer to a query string. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Section 6.3. The response is sent as soon as possible after the instrument receives the query. Typically it takes 10 ms for the instrument to begin the response. Some responses take longer.

6.2.6 Message Flow Control

It is important to remember that the user program is in charge of the serial communication at all times. The instrument can not initiate communication, determine which device should be transmitting at a given time or guarantee timing between messages. All of this is the responsibility of the user program.

When issuing commands only, the user program should:

- Properly format and transmit the command including terminators as one string.
- Guarantee that no other communication is started for 50 ms after the last character is transmitted.
- Not initiate communication more than 20 times per second.

When issuing queries or queries and commands together, the user program should:

- Properly format and transmit the query including terminators as one string.
- Prepare to receive a response immediately.
- Receive the entire response from the instrument including the terminators.
- Guarantee that no other communication is started during the response or for 50 ms after it completes.
- Not initiate communication more than 20 times per second.

Failure to follow these simple rules will result in inability to establish communication with the instrument or intermittent failures in communication.

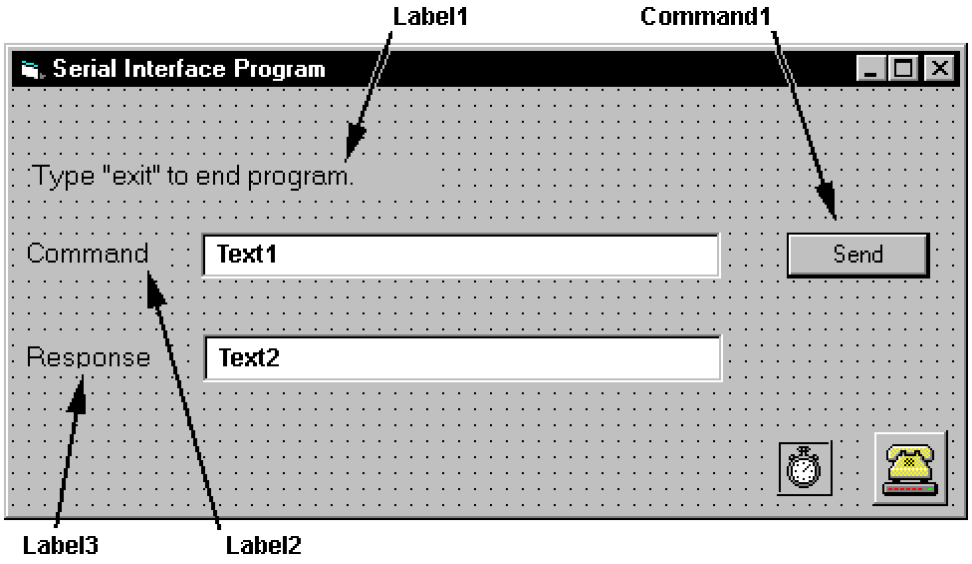
6.2.7 Serial Interface Example Program

A Visual Basic program is included to illustrate the serial communication functions of the instrument. Refer to Section 6.2.7.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 6-8. A description of program operation is provided in Section 6.2.7.2. While the hardware and software required to produce and implement this program is not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

6.2.7.1 Visual Basic Serial Interface Program Setup

The serial interface program works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better, with a serial interface. It uses the COM1 communications port at 9600 Baud. Use the following procedure to develop the Serial Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, click Components to bring up a list of additional controls available in VB6.
5. Scroll through the controls and select Microsoft Comm Control 6.0. Select OK. In the toolbar at the left of the screen, the Comm Control will have appeared as a telephone icon.
6. Select the Comm control and add it to the form.
7. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
   d. Add one Timer control to the form.
8. On the View Menu, select Properties Window.
9. In the Properties window, use the dropdown list to select between the different controls of the current project.

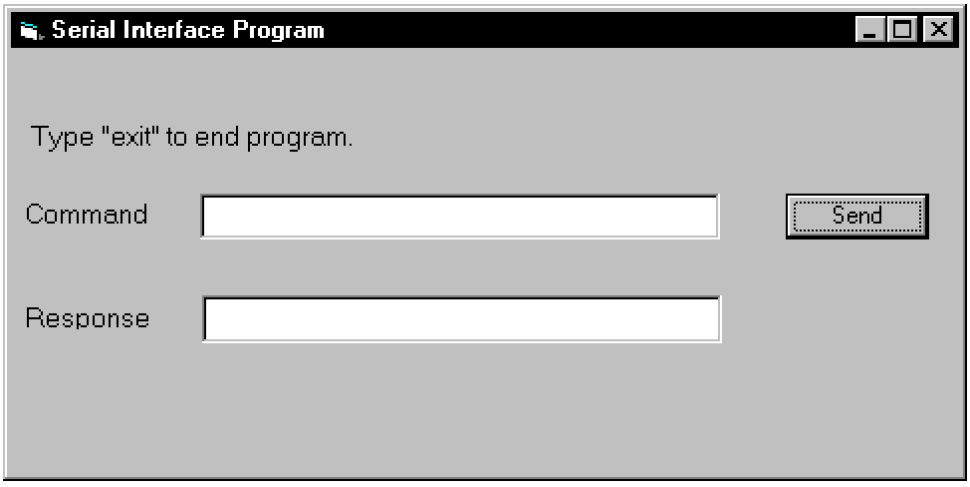


10. Set the properties of the controls as defined in Table 6-7.
11. Save the program.

Table 6-7. Serial Interface Program Control Properties

Current Name	Property	New Value
Label1	Name Caption	lblExitProgram Type "exit" to end program.
Label2	Name Caption	lblCommand Command
Label3	Name Caption	lblResponse Response
Text1	Name Text	txtCommand <blank>
Text2	Name Text	txtResponse <blank>
Command1	Name Caption Default	cmdSend Send True
Form1	Name Caption	frmSerial Serial Interface Program
Timer1	Enabled Interval	False 10

12. Add code (provided in Table 6-8).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 6-8.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 6-8.
    d. Double Click on the Timer control. Add code segment under Private Sub Timer1_Timer() as shown in Table 6-8.
    e. Make adjustments to code if different Com port settings are being used.
13. Save the program.
14. Run the program. The program should resemble the following.



15. Type in a command or query in the Command box as described in Section 6.2.7.2.
16. Press Enter or select the Send button with the mouse to send command.
17. Type Exit and press Enter to quit.

Table 6-8. Visual Basic Serial Interface Program

```
Public gSend As Boolean                                 'Global used for Send button state

Private Sub cmdSend_Click()                             'Routine to handle Send button press
   gSend = True                                         'Set Flag to True
End Sub

Private Sub Form_Load()                                 'Main code section
   Dim strReturn As String                              'Used to return response
   Dim strHold As String                                'Temporary character space
   Dim Term As String                                   'Terminators
   Dim ZeroCount As Integer                             'Counter used for Timing out
   Dim strCommand As String                             'Data string sent to instrument

   frmSerial.Show                                       'Show main window
   Term = Chr(13) & Chr(10)                             'Terminators are <CR><LF>
   ZeroCount = 0                                        'Initialize counter
   strReturn = ""                                       'Clear return string
   strHold = ""                                         'Clear holding string
   If frmSerial.MSComm1.PortOpen = True Then            'Close serial port to change settings
       frmSerial.MSComm1.PortOpen = False
   End If
   frmSerial.MSComm1.CommPort = 1                       'Example of Comm 1
   frmSerial.MSComm1.Settings = "9600,o,7,1"            'Example of 9600 Baud,Parity,Data,Stop
   frmSerial.MSComm1.InputLen = 1                       'Read one character at a time
   frmSerial.MSComm1.PortOpen = True                    'Open port

 Do
   Do                                                   'Wait loop
   DoEvents                                             'Give up processor to other events
   Loop Until gSend = True                              'Loop until Send button pressed
   gSend = False                                        'Set Flag as false

   strCommand = frmSerial.txtCommand.Text               'Get Command
   strReturn = ""                                       'Clear response display

   strCommand = UCase(strCommand)                       'Set all characters to upper case
   If strCommand = "EXIT" Then                          'Get out on EXIT
       End
   End If

   frmSerial.MSComm1.Output = strCommand & Term         'Send command to instrument
   If InStr(strCommand, "?") <> 0 Then                  'Check to see if query
       While (ZeroCount < 20) And (strHold <> Chr$(10))  'Wait for response
           If frmSerial.MSComm1.InBufferCount = 0 Then   'Add 1 to timeout if no character
               frmSerial.Timer1.Enabled = True
               Do
               DoEvents                                 'Wait for 10 millisecond timer
               Loop Until frmSerial.Timer1.Enabled = False
               ZeroCount = ZeroCount + 1                'Timeout at 2 seconds
           Else
               ZeroCount = 0                            'Reset timeout for each character
               strHold = frmSerial.MSComm1.Input        'Read in one character
               strReturn = strReturn + strHold          'Add next character to string
           End If
       Wend                                             'Get characters until terminators

       If strReturn <> "" Then                          'Check if string empty
           strReturn = Mid(strReturn, 1, InStr(strReturn, Term) - 1)  'Strip terminators
       Else
           strReturn = "No Response"                    'Send No Response
       End If
       frmSerial.txtResponse.Text = strReturn           'Put response in textbox on main form
       strHold = ""                                     'Reset holding string
       ZeroCount = 0                                    'Reset timeout counter
   End If
 Loop
End Sub

Private Sub Timer1_Timer()                              'Routine to handle Timer interrupt
   frmSerial.Timer1.Enabled = False                     'Turn off timer
End Sub
```

6.2.7.2 Program Operation

Once the example program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

ENTER COMMAND? ***IDN?**	Identification query. Instrument will return a string identifying itself.
RESPONSE: LSCI,MODEL455,1234567,02032003[term]	
ENTER COMMAND? **RDGFIELD?**	Field reading query. Instrument will return a string with the present field reading in the present units.
RESPONSE: +273.150E+00[term]	
ENTER COMMAND? **RANGE 1**	Field range command. Instrument will set to the lowest range. No response will be sent.
ENTER COMMAND? **RANGE?**	Field range query. Instrument will return a string with the present field range setting.
RESPONSE: 1[term]	
ENTER COMMAND? **RANGE 5;RANGE?**	Field range command followed by a query. Instrument will change to the highest range setting then return a string
RESPONSE: 5[term]	with the present setting.

The following are additional notes on using either Serial Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but are sent in response to a query. A leading "+" is not required but a leading "–" *is* required.

6.2.8 Troubleshooting

New Installation

1. Check instrument Baud rate.
2. Make sure transmit (TD) signal line from the instrument is routed to receive (RD) on the computer and vice versa. (Use a null modem adapter if not).
3. Always send terminators.
4. Send entire message string at one time including terminators. (Many terminal emulation programs do not.)
5. Send only one simple command at a time until communication is established.
6. Be sure to spell commands correctly and use proper syntax.

Old Installation No Longer Working

7. Power instrument off then on again to see if it is a soft failure.
8. Power computer off then on again to see if communication port is locked up.
9. Verify that Baud rate has not been changed on the instrument during a memory reset.
10. Check all cable connections.

Intermittent Lockups

11. Check cable connections and length.
12. Increase delay between all commands to 100 ms to make sure instrument is not being over loaded.

6.3 COMMAND SUMMARY

This paragraph provides a listing of the IEEE-488 and Serial Interface Commands. A summary of all the commands is provided in Table 6-9. All the commands are detailed in Section 6.3.1, presented in alphabetical order.

Sample Command Format

IEEE	IEEE-488 Interface Parameter Command	
Input:	**IEEE <terminator>, <EOI enable>, <address>[term]**	
Format:	n,n,nn	
	<terminator>	Specifies the terminator. Valid entries: 0 = <CR><LF>,1 = <LF><CR>, 2 = <LF>, 3 = no terminator (must have EOI enabled).
	<EOI enable>	Sets EOI mode: 0 = enabled, 1 = disabled.
	<address>	Specifies the IEEE address: 1 – 30. (Address 0 and 31 are reserved.)
Example:	**IEEE 0,0,4[term]** – After receipt of the current terminator, the instrument uses EOI mode, uses <CR><LF> as the new terminator, and responds to address 4.	

Sample Query Format

IEEE?	IEEE-488 Interface Parameter Query	
Input:	**IEEE?[term]**	
Returned:	<terminator>, <EOI enable>, <address>[term]	
Format:	n,n,nn	(Refer to command for description)

Key

✱	Begins common interface command.
?	Required to identify queries.
aa…	String of alpha numeric characters.
±nnn.nnnE±nn	Number represented in scientific notation format.
[term]	Terminator characters.
<…>	Indicated a parameter field, many are command specific.
<state>	Parameter field with only On/Off states.

NOTE: Any number being represented in scientific notation may also be entered as a string of number characters. The following example shows two different ways of sending the same command. Refer to the individual command descriptions for further details.

RELSP 2.0E+03[term]	Command will set the Relative setpoint value to 2000.
RELSP 2000[term]	Command will set the Relative setpoint value to 2000.

Table 6-9. Command Summary

Command	Function	Page
✱CLS	Clear Interface Cmd	6-26
✱ESE	Standard Event Status Enable Register Cmd	6-26
✱ESE?	Standard Event Status Enable Register Query	6-26
✱ESR?	Standard Event Status Register Query	6-26
✱IDN?	Identification Query	6-26
✱OPC	Operation Complete Cmd	6-26
✱OPC?	Operation Complete Query	6-27
✱RST	Reset Instrument Cmd	6-27
✱SRE	Service Request Enable Register Cmd	6-27
✱SRE?	Service Request Enable Register Query	6-27
✱STB?	Status Byte Query	6-27
✱TST?	Self-Test Query	6-27
✱WAI	Wait-To-Continue Cmd	6-27
ALARM	Alarm Parameter Cmd	6-28
ALARM?	Alarm Parameter Query	6-28
ALARMST?	Alarm Status Query	6-28
ANALOG	Analog Output 3 Parameter Cmd	6-28
ANALOG?	Analog Output 3 Parameter Query	6-29
AOUT?	Analog Output 3 Data Query	6-29
AUTO	Auto Range Command	6-29
AUTO?	Auto Range Query	6-29
BAUD	RS-232 Baud Rate Cmd	6-29
BAUD?	RS-232 Baud Rate Query	6-29
BEEP	Audible Alarm Beeper Cmd	6-29
BEEP?	Audible Alarm Beeper Query	6-29
BRIGT	Display Brightness Cmd	6-29
BRIGT?	Display Brightness Query	6-30
DFLT	Factory Defaults Cmd	6-30
DISPLAY	Display Configuration Cmd	6-30
DISPLAY?	Display Configuration Query	6-30
IEEE	IEEE-488 Interface Parameter Cmd	6-30
IEEE?	IEEE-488 Interface Parameter Query	6-30
KEYST?	Keypad Status Query	6-30
LOCK	Front Panel Keyboard Lock Cmd	6-31
LOCK?	Front Panel Keyboard Lock Query	6-31
MXHOLD	Max Hold Cmd	6-31
MXHOLD?	Max Hold Query	6-31
MXRST	Max Hold Reset Cmd	6-31
MODE	Remote Interface Mode Cmd	6-31
MODE?	Remote Interface Mode Query	6-31
OPST?	Operational Status Query	6-32
OPSTE	Operational Status Enable Cmd	6-32
OPSTE?	Operational Status Enable Query	6-32
OPSTR?	Operational Status Register Query	6-32
PKRST	Peak Hold Reset Cmd	6-32
PRBFCOMP	Probe Field Compensation Cmd	6-32
PRBFCOMP?	Probe Field Compensation Query	6-32
PRBSENS?	Probe Sensitivity Query	6-33
PRBSNUM?	Probe Serial Number Query	6-33
PRBTCOMP	Probe Temperature Compensation Cmd	6-33
PRBTCOMP?	Probe Temperature Compensation Query	6-33
RANGE	Field Range Cmd	6-33
RANGE?	Field Range Query	6-33
RDGFIELD?	Field Reading Query	6-33
RDGMODE	Measurement Mode Cmd	6-34
RDGMODE?	Measurement Mode Query	6-34
RDGFRQ?	Frequency Reading Query	6-34
RDGMNMX?	Minimum and Maximum Reading Query	6-34
RDGOHM?	Resistance Reading Query	6-34
RDGPEAK?	Peak Reading Query	6-34
RDGREL?	Relative Reading Query	6-35
RDGTEMP?	Probe Temperature Reading Query	6-35
REL	Relative Mode Cmd	6-35
REL?	Relative Mode Query	6-35
RELAY	Relay Parameter Cmd	6-35
RELAY?	Relay Parameter Query	6-35
RELAYST?	Relay Status Query	6-36
RELSP	Relative Setpoint Cmd	6-36
RELSP?	Relative Setpoint Query	6-36
TUNIT	Probe Temperature Units Cmd	6-36
TUNIT?	Probe Temperature Units Query	6-36
TYPE?	Probe Type Query	6-36
UNIT	Field Units Cmd	6-37
UNIT?	Field Units Query	6-37
ZCLEAR	Clear Zero Probe Cmd	6-37
ZPROBE	Zero Probe Cmd	6-37

6.3.1 Interface Commands (Alphabetical Listing)

***CLS** Clear Interface Command

Input: ***CLS [term]**

Remarks: Clears the bits in the Standard Event Status Register and Operation Event Register and terminates all pending operations. Clears the interface, but *not* the instrument. The related instrument command is ***RST**.

***ESE** Standard Event Status Enable Register Command

Input: ***ESE <bit weighting>[term]**

Format: nnn

Remarks: The Standard Event Status Enable Register determines which bits in the Standard Event Status Register will set the summary bit in the Status Byte. This command programs the enable register using a decimal value which corresponds to the binary-weighted sum of all bits in the register. Refer to Section 6.1.4.2.1.

***ESE?** Standard Event Status Enable Register Query

Input: ***ESE? [term]**

Returned: <bit weighting>[term]

Format: nnn (Refer to command for description)

***ESR?** Standard Event Status Register Query

Input: ***ESR? [term]**

Returned: <bit weighting>

Format: nnn

Remarks: Bits in this register correspond to various system events and latch when the event occurs. When an event bit is set, subsequent events corresponding to that bit are ignored. Set bits remain latched until the register is reset by this query or a *CLS command. Refer to Section 6.1.4.2.1.

***IDN?** Identification Query

Input: ***IDN? [term]**

Returned: <manufacturer>,<model>,<serial>,<date>[term]

Format: aaaa,aaaaaaaa,aaaaaaa,mmddyyyy

<manufacture>	Manufacturer ID
<model>	Instrument model number
<serial>	Serial number
<date>	Instrument firmware revision date

Example: **LSCI,MODEL455,1234567,06122003**

***OPC** Operation Complete Command

Input: ***OPC [term]**

Remarks: Used in conjunction with bit 0 (OPC of the Standard Event Status Register. If sent as the last command in a command sequence, bit 0 will be set when the instrument completes the operation that was initiated by the command sequence. Refer to Section 6.1.4.3.6 for more information.

***OPC?** Operation Complete Query

Input: *OPC? [term]

Returned: 1[term]

Remarks: Has *no* interaction with bit 0 (OPC) of the Standard Event Status Register. If sent at the end of a command sequence, the bus will be held until the instrument completes the operation that was initiated by the command sequence. Once the sequence is complete a 1 will be placed in the output buffer. Refer to Section 6.1.4.3.6 for more information.

***RST** Reset Instrument Command

Input: *RST[term]

Remarks: Sets controller parameters to power-up settings. Use the **DFLT** command to set factory defaults.

***SRE** Service Request Enable Register Command

Input: *SRE <bit weighting>[term]

Format: nnn

Remarks: The Service Request Enable Register determines which summary bits of the Status Byte may set bit 6 (RQS/MSS) of the Status Byte to generate a Service Request. This command programs the enable register using a decimal value which corresponds to the binary-weighted sum of all bits in the register. Refer to Section 6.1.4.3

***SRE?** Service Request Enable Register Query

Input: *SRE? [term]

Returned: <bit weighting>[term]

Format: nnn (Refer to command for description)

***STB?** Status Byte Query

Input: *STB? [term]

Returned: <bit weighting>[term]

Format: nnn

Remarks: This command is similar to a Serial Poll except it is processed like any other instrument command. It returns the same result as a Serial Poll except that the Status Byte bit 6 (RQS/MSS) is not cleared. Refer to Section 6.1.4.3.4

***TST?** Self-Test Query

Input: *TST? [term]

Returned: <status>[term]

Format: n

<status> 0 = No errors found, 1 = Errors found

Remarks: The Model 455 reports status based on test done at power up.

***WAI** Wait-to-Continue Command

Input: *WAI [term]

Remarks: This command is not supported in the Model 455.

ALARM Alarm Parameter Command

Input: `ALARM <off/on>, <mode>, <low value>, <high value>,<out/in>[term]`

Format: n,n,±nnn.nnnE±nn,±nnn.nnnE±nn,n

<off/on> Specifies alarm checking on or off: 0 = Off, 1 = On.

<mode> Specifies checking magnitude(absolute value used) or algebraically(includes sign): 1 = Magnitude check, 2 = Algebraic check.

<low value> Sets the value the source is checked against to activate the low alarm: ±350 kG

<high value> Sets the value the source is checked against to activate high alarm: ±350 kG

<out/in> Specifies the alarm to trigger on value outside or inside of setpoints: 1= Outside, 2 = Inside.

Examples: **ALARM 1,1,100,300,1[term] –** Turns alarm checking on. Activates alarm if the absolute value of the field is over 300 Gauss, or if the absolute value of the field is below 100 Gauss.

ALARM 1,2,-100,300,2[term] – Turns alarm checking on. Activates alarm if the value of the field is between –100 Gauss and +300 Gauss.

ALARM? Alarm Parameter Query

Input: `ALARM? [term]`

Returned: <off/on>, <mode>, <low value>, <high value>,<out/in> [term]

Format: n,n,±nnn.nnnE±nn,±nnn.nnnE±nn,n (Refer to command for description)

ALARMST? Alarm Status Query

Input: `ALARMST? [term]`

Returned: <state> [term]

Format: n
< state> 0 = Off, 1 = On

ANALOG Analog Output 3 Parameter Command

Input: `ANALOG <mode>, <polarity>, <low value>, <high value>, <manual value>, <voltage limit> [term]`

Format: n,n,±nnn.nnnE±nn,±nnn.nnnE±nn, ±nnn.nnnE±nn ,nn

<mode> Specifies data the analog out 3 monitors: 0 = off, 1 = default, 2 = user defined, 3 = manual

<polarity> Specifies analog output polarity: 1 = unipolar, 2 = bipolar.

<low value> If <mode> is 2, this parameter represents the data at which the analog output reaches –100% output if bipolar, or 0% output if unipolar: ±350 kG

<high value> If <mode> is 2, this parameter represents the data at which the analog output reaches +100% output: ±350 kG

<manual value> If <mode> is 3, this parameter represents the percent output of the analog output between –100% and +100%.

<voltage limit> Specifies absolute maximum analog output voltage: 1 to 10 V

Example: **ANALOG 2,2,25.000E-3,250.000E-3,0.00000E+00,10[term]** – Configures Analog Output 3 for user defined mode, bipolar polarity, –100% out at 25 mG, +100% out at 250 mG, and an absolute maximum output voltage of 10 V. The manual value is ignored in this mode.

ANALOG? Analog Output 3 Parameter Query

Input: `ANALOG? [term]`

Returned: <mode>, <polarity>, <low value>, <high value>, <manual value>, <voltage limit> [term]

Format: n,n,±nnn.nnnE±nn,±nnn.nnnE±nn,±nnn.nnnE±nn (Refer to command for definition)

AOUT? Analog Output 3 Data Query

Input: `AOUT? [term]`

Returned: <percent>[term]

Format: ±nnn.nnnE±nn

Remarks: Returns the percentage of output of Analog Out 3.

AUTO Auto Range Command

Input: `AUTO <off/on>[term]`

Format: n

<off/on> Specifies autorange on or off: 0 = Off, 1 = On.

Example: **AUTO 1 [term]** – Turns on the autorange feature.

AUTO? Auto Range Query

Input: `AUTO? [term]`

Returned: <off/on>[term]

Format: n (Refer to command for description)

BAUD RS-232 Baud Rate Command

Input: `BAUD <bps>[term]`

Format: n

<bps> 1 = 9600 Baud, 2 = 19200 Baud, 3 = 38400 Baud, 4 = 57600 Baud.

BAUD? RS-232 Baud Rate Query

Input: `BAUD?[term]`

Returned: <bps>[term]

Format: n (Refer to command for description)

BEEP Alarm Beeper Command

Input: `BEEP <state>[term]`

Format: n

<state> 0 = Off, 1 = On.

Remarks: Enables or disables system beeper sound when an alarm condition is met.

BEEP? Alarm Beeper Query

Input: `BEEP? [term]`

Returned: <state>[term]

Format: n (Refer to command for description)

BRIGT Display Brightness Command

Input: `BRIGT <bright>[term]`

Format: n

<bright> 1 = 25%, 2 = 50%, 3 = 75%, 4 = 100%. Default = 3.

BRIGT?

Display Brightness Query

Input: `BRIGT? [term]`

Returned: <bright>[term]

Format: n (Refer to command for description)

DFLT

Factory Defaults Command

Input: `DFLT 99 [term]`

Remarks: Sets all configuration values to factory defaults and resets the instrument. The "99" is included to prevent accidentally setting the unit to defaults.

DISPLAY

Display Configuration Command

Input: `DISPLAY <item>[term]`

Format: n

<item> Specifies the item to display on line 2: 1 – 4

1 = Blank
2 = Field
3 = Probe Temperature and Frequency (if available)
4 = Relative setpoint

Example: **DISPLAY 3[term]** – Probe Temperature will be displayed on Line 2 if the probe is capable of measuring temperature. The Frequency will also be displayed if the Model 455 is in RMS mode.

DISPLAY?

Display Configuration Query

Input: `DISPLAY? [term]`

Returned: <item>[term]

Format: n (Refer to command for description)

IEEE

IEEE-488 Interface Parameter Command

Input: `IEEE <terminator>, <EOI enable>, <address>[term]`

Format: n,n,nn

<terminator> Specifies the terminator. Valid entries: 0 = <CR><LF>,1 = <LF><CR>, 2 = <LF>, 3 = no terminator (must have EOI enabled).

<EOI enable> Sets EOI mode: 0 = enabled, 1 = disabled.

<address> Specifies the IEEE address: 1 – 30. (Address 0 and 31 are reserved.)

Example: **IEEE 0,0,4[term]** – After receipt of the current terminator, the instrument uses EOI mode, uses <CR><LF> as the new terminator, and responds to address 4.

IEEE?

IEEE-488 Interface Parameter Query

Input: `IEEE? [term]`

Returned: <terminator>, <EOI enable>, <address>[term]

Format: n,n,nn (Refer to command for description)

KEYST?

Keypad Status Query

Input: `KEYST?[term]`

Returned: <keypad status>[term]

Format: nn

Remarks: Returns a number descriptor of the last key pressed since the last KEYST?.
KEYST? returns 1 after initial power-up. Returns a 0 if no key pressed since last query.

LOCK

Front Panel Keyboard Lock Command

Input: `LOCK <state>, <code>[term]`

Format: n,nnn

<state> 0 = Unlocked, 1 = Locked

<code> Specifies lock-out code. Valid entries are 000 – 999.

Remarks: Locks out all front panel entries.

Example: **LOCK 1,123[term] –** Enables keypad lock and sets the code to 123.

LOCK?

Front Panel Keyboard Lock Query

Input: `LOCK?[term]`

Returned: <state>, <code>[term]

Format: n,nnn (Refer to command for description)

MXHOLD

Max Hold Command

Input: `MXHOLD <off/on>,<mode>,<display>[term]`

Format: n,n,n

<off/on> Specifies Max Hold on or off: 0 = off and 1 = on.

<mode> Specifies checking magnitude(absolute value used) or algebraically(includes sign): 1 = Magnitude check, 2 = Algebraic check.

<display> Specifies Display configuration when Max Hold is on: 1 = Display Maximum value on top line, 2 = Display Minimum value on top line, 3 = Display Both, Max on top line and Minimum on bottom line. This overrides the DISPLAY command configuration.

Example: **MXHOLD 1,1,2[term] –** Turns the Max Hold feature on using the Magnitude checking mode. The Model 455 displays both Max and Min values.

MXHOLD?

Max Hold Query

Input: `MODE? [term]`

Returned: <off/on>,<mode>,<display> [term]

Format: n,n,n (Refer to command for description)

MXRST

Max Hold Reset Command

Input: `MXRST [term]`

Remarks: Resets the minimum and maximum stored field readings and sets them equal to the present reading.

MODE

Remote Interface Mode Command

Input: `MODE <mode>[term]`

Format: n

<mode> 0 = local, 1 = remote, 2 = remote with local lockout.

Example: **MODE 2[term] –** Places the Model 455 into remote mode with local lockout.

MODE?

Remote Interface Mode Query

Input: `MODE? [term]`

Returned: <mode>[term]

Format: n (Refer to command for description)

OPST? Operational Status Query

Input: `OPST? [term]`

Returned: <bit weighting> [term]

Format: nnn

Remarks: The integer returned represents the sum of the bit weighting of the operational status bits. Refer to Section 6.1.4.2.2 for a list of operational status bits.

OPSTE Operational Status Enable Command

Input: `OPSTE <bit weighting>[term]`

Format: nnn

Remarks: Each bit has a bit weighting and represents the enable/disable mask of the corresponding operational status bit in the Operational Status Register. This determines which status bits can set the corresponding summary bit in the Status Byte Register. To enable a status bit, send the command **OPSTE** with the sum of the bit weighting for each desired bit. Refer to Section 6.1.4.2.2 for a list of operational status bits.

OPSTE? Operational Status Enable Query

Input: `OPSTE? [term]`

Returned: <bit weighting> [term]

Format: nnn Refer to Section 6.1.4.2.2 for a list of operational status bits.

OPSTR? Operational Status Register Query

Input: `OPSTR? [term]`

Returned: <bit weighting> [term]

Format: nnn

Remarks: The integers returned represent the sum of the bit weighting of the operational status bits. These status bits are latched when the condition is detected. This register is cleared when it is read. Refer to Section 6.1.4.2.2 for a list of operational status bits.

PKRST Peak Hold Reset Command

Input: `PKRST [term]`

Remarks: Resets the stored positive and negative peak field readings and sets them equal to zero. This is only valid in Pulse measurement mode.

PRBFCOMP Probe Field Compensation Command

Input: `PRBFCOMP <off/on>[term]`

Format: n

<off/on> Specifies Probe Field compensation off or on. Valid entries: 0 = off, 1 = on.

Example: **PRBFCOMP 1[term]** – Field Measurement uses the Probe Field Compensation table

PRBFCOMP? Probe Field Compensation Query

Input: `PRBFCOMP? [term]`

Returned: <off/on>[term]

Format: n (Refer to command for description)

PRBSENS? Probe Sensitivity Query

Input: `PRBSENS? [term]`
Returned: <sensitivity>[term]
Format: ±nnn.nnnE±nn
Remarks: Returns the probe sensitivity in mV/kG.

PRBSNUM? Probe Serial Number Query

Input: `PRBSNUM? [term]`
Returned: <type>[term]
Format: xxxxxxxxxx
Remarks: Returns the probe serial number.

PRBTCOMP Probe Temperature Compensation Command

Input: `PRBTCOMP <off/on>[term]`
Format: n
<off/on> Specifies Probe Temperature compensation off or on. Valid entries: 0 = off, 1 = on.
Example: **PRBTCOMP 1[term]** – Field Measurement is compensated for present probe temperature.

PRBTCOMP? Probe Temperature Compensation Query

Input: `PRBTCOMP? [term]`
Returned: <off/on>[term]
Format: n (Refer to command for description)

RANGE Field Range Command

Input: `RANGE <range>[term]`
Format: n
<range> Specifies range from lowest to highest: 1 – 5. (Field values are probe dependent.)
Example: RANGE 4 [term] – Sets the present range to 4.

RANGE? Field Range Query

Input: `RANGE? [term]`
Returned: <range>[term]
Format: n (Refer to command for description)

RDGFIELD? Field Reading Query

Input: `RDGFIELD? [term]`
Returned: <field>[term]
Format: ±nnn.nnnE±nn
Remarks: Returns the field reading in a format based on the present units. This is valid for DC or RMS.

RDGMODE Measurement Mode Command

Input: **RDGMODE <mode>, <dc resolution>, <rms measurement mode>, <peak mode>, <peak disp>[term]**

Format: n,n,n,n,n

<mode>	Specifies the measurement mode: 1 = DC, 2 = RMS, 3 = peak.
<dc resolution>	DC operating resolution in number of digits: 1 = 3 digits, 2 = 4 digits, 3 = 5 digits
<rms measurement mode>	RMS measurement mode: 1 = wide band, 2 = narrow band.
<peak mode>	Specifies peak measurement mode: 1 = periodic, 2 = pulse.
<peak disp>	Specifies display of peak reading: 1 = positive, 2 = negative, 3 = both.

Example: **RDGMODE 1,3,1,1,1[term]** – The Model 455 is configured for DC field measurement, DC resolution of 5 digits, wide band rms filter mode, peak measurement mode is periodic, and positive peak readings will be displayed if the measurement mode is changed to peak.

RDGMODE? Measurement Mode Query

Input: **RDGMODE? [term]**

Returned: <mode>, <dc resolution>, <rms measurement mode>, <peak mode>, <peak disp>[term]

Format: n,n,n,n,n (Refer to command for description)

RDGFRQ? Frequency Reading Query

Input: **RDGFRQ? [term]**

Returned: <frequency>[term]

Format: ±nnn.nnnE±nn

Remarks: Returns the frequency reading in Hz. The instrument must be in RMS for this to be valid.

RDGMNMX? Minimum and Maximum Reading Query

Input: **RDGMNMX? [term]**

Returned: <min>,<max>[term]

Format: ±nnn.nnnE±nn, ±nnn.nnnE±nn

Remarks: Returns the most recent minimum and maximum field readings.

RDGOHM? Resistance Reading Query

Input: **RDGOHM? [term]**

Returned: <hall resistance>[term]

Format: ±nnn.nnnE±nn

Remarks: Returns the Hall resistance of the sensor.

RDGPEAK? Peak Reading Query

Input: **RDGPEAK? [term]**

Returned: <negative peak>,<positive peak> [term]

Format: ±nnn.nnnE±nn, ±nnn.nnnE±nn

Remarks: Returns the negative and positive peak readings.

RDGREL? Relative Reading Query

Input: `RDGREL? [term]`

Returned: <relative reading>[term]

Format: ±nnn.nnnE±nn

Remarks: Returns the relative field reading.

RDGTEMP? Probe Temperature Reading Query

Input: `RDGTEMP? [term]`

Returned: <temperature>[term]

Format: ±nnn.nnnE±nn

Remarks: Returns the probe temperature reading in a format based on the present temperature units.

REL Relative Mode Command

Input: `REL <off/on>, <setpoint source>[term]`

Format: n,n

<off/on> Specifies Relative mode off or on: 0 = off, 1 = on.

<setpoint source> Specifies source of relative setpoint: 1 = User defined, 2 = Present Field.

Example: **REL 1,1 [term]** – Relative mode turned on, configured to use the User defined setpoint. Refer to RELSP command.

REL? Relative Mode Query

Input: `REL? [term]`

Returned: <off/on>, <setpoint source>[term]

Format: n,n (Refer to command for description)

RELAY Relay Parameter Command

Input: `RELAY <relay number>, <mode>, <alarm type>[term]`

Format: n,n,n

<relay number> Specifies which relay to configure: 1 = Relay 1, 2 = Relay 2.

<mode> Specifies relay mode: 0 = Off, 1 = On, 2 = Alarms.

<alarm type> Specifies the alarm type that activates the relay when the relay is in alarm mode: 1 = Low Alarm, 2 = High Alarm, 3 = Both Alarms.

Example: **RELAY 1,2,2[term]** – Relay 1 is setup in Alarms mode and activates when the low alarm activates.

RELAY? Relay Parameter Query

Input: `RELAY? <relay number>[term]`

Format: n

<relay number> Specifies which relay to query: 1–2.

Returned: <mode>, <alarm type>[term]

Format: n,n (Refer to command for description)

RELAYST? Relay Status Query

Input: `RELAYST? <relay number>[term]`

Format: n
<relay number> Specifies which relay to query: 1 = Relay 1, 2 = Relay 2.

Returned: <status>[term]

Format: n 0 = Off, 1 = On.

RELSP Relative Setpoint Command

Input: `RELSP <setpoint>[term]`

Format: ±nnn.nnnE±nn
<setpoint> Specifies the setpoint to use in the relative calculation: ±350 kG

Example: **RELSP 1200[term]** – Configure the relative setpoint as 1200 Gauss(if units in Gauss). The relative reading will use this value if relative is using the user defined setpoint. Refer to REL command.

RELSP? Relative Setpoint Query

Input: `RELSP? [term]`

Returned: <setpoint>[term]

Format: ±nnn.nnnE±nn (Refer to command for description)

TUNIT Probe Temperature Units Command

Input: `TUNIT <units>[term]`

Format: n
<units> 1 = Celsius, 2 = Kelvin

Example: **TUNIT 1[term] –** Configures the Model 455 to report probe temperature in °C.

TUNIT? Probe Temperature Units Query

Input: `TUNIT? [term]`

Returned: <units>[term]

Format: n (Refer to command for description)

TYPE? Probe Type Query

Input: `TYPE? [term]`

Returned: <type>[term]

Format: nn

Remarks: Returns the probe type:
- 40 = high sensitivity
- 41 = high stability
- 42 = ultra-high sensitivity
- 50 = user programmable cable/high sensitivity probe
- 51 = user programmable cable/high stability probe
- 52 = user programmable cable/ultra-high sensitivity probe

UNIT Field Units Command

Input: `UNIT <units>[term]`

Format: n

<units> 1 = Gauss, 2 = Tesla, 3 = Oersted, 4 = Amp/meter.

Example: **UNIT 2[term] –** Configures the Model 455 to report readings in Tesla.

UNIT? Field Units Query

Input: `UNIT? [term]`

Returned: <units>[term]

Format: n (Refer to command for description)

ZCLEAR Clear Zero Probe Command

Input: `ZCLEAR [term]`

Remarks: Resets the value stored from the ZPROBE command.

ZPROBE Zero Probe Command

Input: `ZPROBE [term]`

Remarks: Initiates the Zero Probe function. Place the probe in zero gauss chamber before issuing this command.

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CHAPTER 7

PROBES AND ACCESSORIES

7.0 GENERAL

This chapter provides information on the accessories and probes available for the Model 455 DSP Gaussmeter.

7.1 MODELS

The list of Model 455 Model numbers is provided as follows.

Model	Description
455	**Standard Model 455 DSP Gaussmeter.** Power is configured as shown below.

Power Configurations. The instrument is configured at the factory for customer-selected power as follows.

1	100 V – US cord (NEMA 5-15)
2	120 V – US cord (NEMA 5-15)
3	220 V – Euro cord (CEE 717)
4	240 V – Euro cord (CEE 717)
5	240 V – UK cord (BS 1363)
6	240 V – Swiss cord (SEV 1011)
7	220 V – China cord (GB 1002)

7.2 ACCESSORIES

Accessories are devices that perform a secondary duty as an aid or refinement to the primary unit. A list of accessories available for the Model 455 is as follows:

Model	Description Of Accessories
G-106-253 *	**25-pin D-Sub Plug.** Used for I/O mating connector.
G-106-264 *	**25-pin D-Sub Shell.** Used for I/O mating connector.
4005	**IEEE-488 Cable Kit.** One meter (3 feet) long IEEE-488 (GPIB) computer interface cable assembly. Includes extender required to use both IEEE cable and Auxiliary I/O connector simultaneously.
4060 *	**Standard Zero Gauss Chamber.** For standard probe offset nulling. Size: 32 × 32 × 61 mm (1.3 × 1.3 × 2.4 in.). Bore: 12 mm diameter × 51 mm deep (0.5 × 2 in.). See Figure 7-17.
4065	**Large Zero Gauss Chamber.** For Gamma Probe offset nulling. Size: 57 × 53 × 305 mm (2.3 × 2 × 12 in.). Bore: 19 mm diameter × 279 mm deep (0.75 × 11 in.). See Figure 7-18.
MAN-455 *	**Model 455 Gaussmeter User's Manual.**
RM-1/2	**Half-Rack Mounting Kit for One 1/2 Rack Gaussmeter.** Half-length mounting panel and mounting ears to attach one Model 455 to a 483 mm (19-inch) rack mount space. See Figure 3-7.
RM-2	**Dual Mounting Shelf for Two 1/2 Rack Gaussmeters.** Mounting panel and mounting ears to attach two Model 455 DSP Gaussmeters to a 483 mm (19-inch) rack mount space. See Figure 3-8.

* Accessory included with a new Model 455.

7.3 LAKE SHORE STANDARD PROBES

There are several types of Lake Shore Model 455 probes available: Axial, Gamma, Tangential, and Transverse — generally named for the Hall sensor orientation. Because the Model 455 covers such a wide magnetic field range (0.01 mG to 350 kG), three probe ranges are available: High Stability (HST), High Sensitivity (HSE), and Ultra-High Sensitivity (UHS). Please consult the factory for availability of probe types not detailed in this section.

7.3.1 Hall Probe Selection Criteria

Proper selection of a Hall probe is probably the most difficult, and important, decision to make after choosing the Model 455. Utilizing the wrong probe may lead to less than optimal accuracy or, even worse, costly damage.

Probe Application

Field measurement application is the controlling factor in probe selection. Application dictates the physical manifestation of the measured field, including the parameters described briefly below along with relevant probe characteristics.

Magnitude: Typical Hall probes cover an operating range of four to five orders of field magnitude. Operation beyond this range often requires some compromise in performance, which is often higher noise or loss of resolution. Choosing the correct probe type ensures optimal performance in the desired measurement range.

High Sensitivity (HSE): High sensitivity probes are the most common for general-purpose field measurement. They operate effectively in fields up to 35 kG (3.5 T) with excellent sensitivity over their entire range. At low fields, their sensitivity can be as low as 5 mG (0.5 μT). HSE probes have a relatively small active area making them convenient for many applications and they are offered in a variety of stem geometries for convenience.

High Stability (HST): With a high field range of up to 350 kG (35 T), high stability probes are used when fields exceed the 35 kG (3.5 T) limit of HSE probes. Their low field performance is slightly degraded with minimum sensitivity of 50 mG (5 μT). High stability probes are also inherently more temperature stable than other probes and should be used when large temperature excursions are expected. The same probe geometries are available for both HST and HSE probes. HST probes are not to be used at frequencies above 800 Hz.

Ultra High Sensitivity (UHS): Low magnitude, large volume fields are most effectively measured with ultra high sensitivity probes that have unbeatable low field resolution to 20 μG (2 nT). UHS probes, or gamma probes, are ideal for measuring fringe fields or variations in Earth's magnetic field. They should never be used in fields over 30 G. UHS probes are larger than other probes and they have a very large active area, making them impractical for small volume fields or tight spaces.

Orientation: Getting to the field is often much of the challenge in selecting a probe. Field orientation dictates the most basic probe geometry choice of transverse verses axial. Other variations are also available for less common, more challenging applications. Listed below are the standard configurations for HSE and HST probes, USH probes require special packaging that is not described here.

Transverse: Transverse probes, most often rectangular in shape, measure fields normal to their stem width. They are useful for most general-purpose field measurements and are essential for work in magnet gaps. Several stem lengths and thicknesses are available as standard probes.

Axial: Axial probes, most often round, measure fields normal to their end. They can also be used for general-purpose measurements but are most commonly used to measure fields produced by solenoids. Several stem lengths and diameters are available as standard probes.

Flexible: Flexible probes are special because they have a flexible portion in the middle of their stem. The active area at the tip remains rigid and somewhat exposed. (Flexible transverse probes are significantly more fragile than other transverse probes.) Flexible probes should only be select for applications that do not have direct access to the measured field with standard transverse or axial probes.

Tangential: Tangential probes are special transverse versions designed to measure fields parallel to and near a surface. The active area is very close to the stem tip. These probes are intended for this special application and should not be selected for general transverse measurements.

Multiple Axis: Multi-axis probes are available for multi-axis gaussmeters like the Lake Shore Model 460. These probes are not compatible with the Model 455.

Frequency: Hall-effect gaussmeters, like the Model 455, are equally well suited for measuring either static, DC fields or periodic, AC fields but proper probe selection is required to get optimal performance.

Metal Stem: Metal stem probes are the best choice for DC and low frequency AC measurements. Non-ferrous metals are used for probe stems because they provide the best protection for the delicate Hall-effect sensor. Aluminum is the most common metal stem material but brass can also be used. Metal stems do have one drawback; eddy currents are formed in them when they are placed in AC fields. These eddy currents oppose the field and cause measurement error. The error magnitude is proportional to frequency and is most noticeable above 800 Hz.

Non-metal Stem: Non-metal stems are required for higher frequency AC fields and for measuring pulse fields but they obviously provide less protection than metal stems. Fiberglass/epoxy is a common non-metal stem material or the Hall-effect sensor can be left exposed on its ceramic substrate. These materials are not conductive so eddy currents do not limit their frequency range but other factors may. Be careful to read and understand the frequency specification of both the probe and gaussmeter when choosing a non-metal probe.

⚠ WARNING: None of these probe types are suitable for direct exposure to high voltage. The possibility exists for damage to equipment or injury to the operator if the probe is exposed to high voltage.

Gradient: Probe selection would be easier if all fields were large and uniform but that is seldom the case because most fields are limited in volume and contain gradients (changes in magnitude). Hall-effect probes measure an average magnitude over their active area making it necessary to understand the relationship between active area and field gradients.

Severe field gradients are always experienced as the active sense element is moved away from a permanent magnet pole making it important to know the distance between the active area and probe tip. The distance between probe tip and active area is specified for axial probes, but is less easily defined for transverse probes.

Nominal Active Area: HSE and HST probes have a nominal active area on the order of 1mm diameter, which is useful for all but the most stringent applications. The measured field is the average over the active area, but without severe gradients the measured value accurately represents the true field. Field mapping with standard probes is also practical if a mapping resolution of 1mm or greater is acceptable.

Small Active Area: HSE and HST probes with a smaller active area are also available from Lake Shore for measurements in severe gradients. They should also be chosen for high resolution mapping applications.

UHS Probes: UHS probes have a very large active length, up to 3.5 in. (8.9 cm). They are designed to measure large, ambient fields with little gradient.

Probe Durability

All Hall effect probes are fragile. The sensor, normally located at the tip of the probe stem, must not be bent, physically shocked or abraded. Many users purchase probes with the thinnest transverse stem or smallest diameter axial stem thinking that these probes should fit all future applications. However, this may be a big mistake. Always use the most robust probe that fits the immediate application. For instance, the HMMT-6J04-VH (aluminum stem) is less prone to damage than the HMFT-3E03-VH (flexible stem). The HMMA-2502-VH (1/4-inch diameter aluminum) is more robust than the HMNA-1904-VH (3/16-inch diameter fiberglass) with its exposed Hall sensor. One last comment about probe handling, never fasten a probe stem to another object. If a probe is to be clamped, always clamp to the handle.

7.3.2 Radiation Effects on Gaussmeter Probes

The HST and HSE probes use a highly doped indium arsenide active material. The HST material is the more highly doped of the two and therefore will be less affected by radiation. Some general information relating to highly doped indium arsenide Hall generators is as follows:

- Gamma radiation seems to have little effect on the Hall generators.
- Proton radiation up to 10 Mrad causes sensitivity changes <0.5%.
- Neutron cumulative radiation (>0.1 MeV, 10^{15}/sq. cm.) can cause a 3% to 5% decrease in sensitivity.
- In all cases the radiation effects seem to saturate and diminish with length of time exposed.

7.3.3 Probe Accuracy Considerations

The user must consider all the possible contributors to the accuracy of the reading. Both the probe and gaussmeter have accuracy specifications that may impact the actual reading. The probe should be zeroed before making critical measurements. The zero probe function is used to null (cancel) out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an open probe (registering Earth's local magnetic field). Users wishing to cancel out large magnetic fields should use the Relative function. Refer to Section 4.6.6.

Probe temperature can also affect readings. Refer to the two separate temperature coefficients listed on the specification sheet. The High Stability (HST) probes exhibit a low temperature coefficient of gain due to the inherent thermal stability of the materials used in their construction.

Probe readings are dependent on the angle of the sensor (Hall sensor) in relation to the magnetic field. Maximum output occurs when the flux vector is perpendicular to the plane of the sensor. This is the condition that exists during factory calibration. The greater the deviation from orthogonality (from right angles in either of three axes), the larger the error of the reading. For example, a 5° variance on any one axis causes a 0.4% error, a 10° misalignment induces a 1.5% error, etc. See Figure 7-1.

Tolerance of instrument, probe, and magnet must be considered for making critical measurements. The accuracy of the gaussmeter reading is typically ±0.05% of reading and ±0.005% of range, but the absolute accuracy readings for gaussmeters and Hall probes is a difficult specification to give, because all the variables of the measurement are difficult to reproduce. Differences in alignment and positioning will degrade measurement accuracy and repeatability. Finally, the best probes have an accuracy of ±0.10%. This implies that the absolute accuracy of a magnetic field measurement will not reliably be better than ±0.10% of reading, and is likely to be 0.15% or higher.

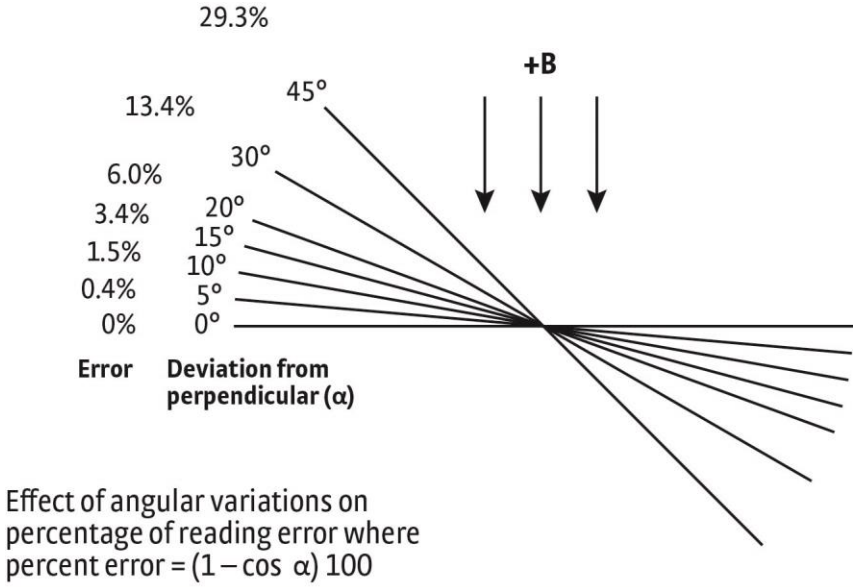


Figure 7-1. Effect Of Angle On Measurements

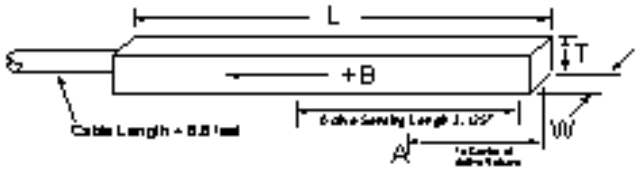
7.3.4 Probe Specifications

Terminology used in Figures 7-2 thru 7-8 are defined as follows:

Definition of Probe Terminology
A = Distance from tip to center line of active area +B = Magnetic flux density vector (for + reading) HST = High Stability Probe HSE = High Sensitivity Probe UHS = Ultra-High Sensitivity Probe

	Usable Full-Scale Ranges Vs. Probe Type			
Type	**HST-3**	**HST-4**	**HSE**	**UHS**
Usable on Ranges	—	—	3.5 G	—
	35 G	35 G	35 G	35 mG
	350 G	350 G	350 G	350 mG
	3.5 kG	3.5 kG	3.5 kG	3.5 G
	35 kG	35 kG	35 kG	35 G
	350 kG	—	—	—

GAMMA PROBE



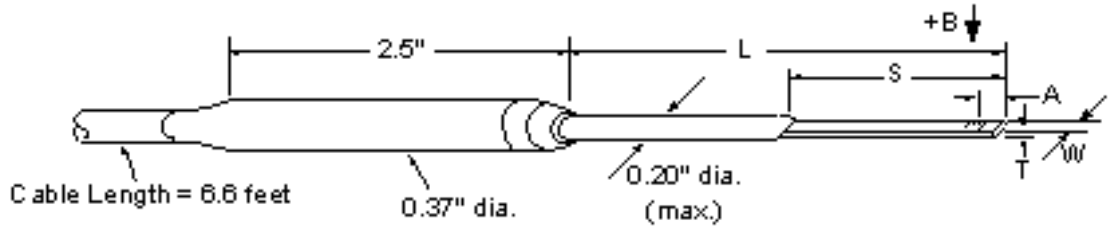
Small variations in, or low values of large volume magnetic fields, such as that of the Earth or large fields around large solenoids, can be measured with these ultra-high sensitivity probes. Resolutions of several gammas (10^{-5} G) are available. Application is optimum when fields are homogeneous over lengths smaller than 1 foot. The active sensing length of the gamma probe is 2.125 inches.

Model No.	W	T	A	L	Frequency Range	Type	Corrected Accuracy (%of Reading)	Operating Temperature Range	Temperature Coefficient (Maximum)		Contain Temperature Sensor
									Zero	Calibration	
HMLA-5006-HJ	0.25 ±0.03"	0.5"	2.2"	5.7"	DC to 400 Hz	UHS	±0.5%to 2 gauss	0 °C to +75 °C	1 mG/°C	±0.02%/°C	Yes

Gamma.eps

Figure 7-2. Definition of Lake Shore Gamma Probe

ROBUST (BRASS STEM) TRANSVERSE PROBES

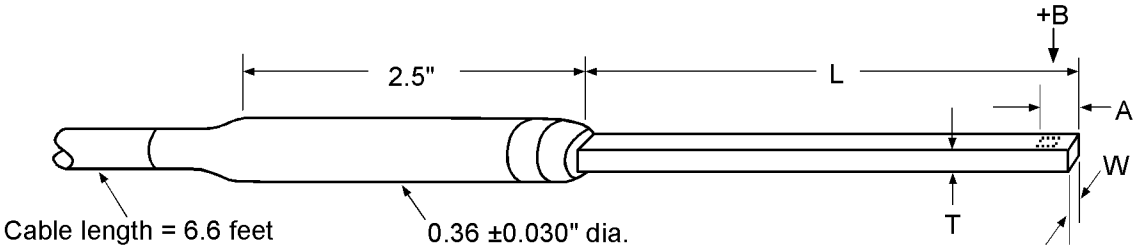


Model No.	L	S	W	T	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (%of Reading)	Operating Temperature Range	Temperature Coefficient (maximum)		Contain Temperature Sensor
												Zero	Calibration	
HMMTB-6J02-VR	2 ±0.125"	1.75"	0.22"	0.061" max	0.150" ±0.050	0.040" dia. approx	Brass	DC	HSE	±0.20% to 30 kG and ±0.25% 30–35 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C	Yes
HMMTB-6J04-VR	4 ±0.125"	3.5" to 4"												
HMMTB-6J08-VR	8 ±0.125"													
HMMTB-6J02-VF	2 ±0.125"	1.75"							HST-4	±0.10% to 30 kG and ±0.15% 30–35 kG		±0.13 G/°C	–0.005%/°C	
HMMTB-6J04-VF	4 ±0.125"	3.5" to 4"												
HMMTB-6J08-VF	8 ±0.125"													

Brass_Transverse.eps

Figure 7-3. Definition of Lake Shore Robust (Brass Stem) Transverse Probes

TRANSVERSE PROBES



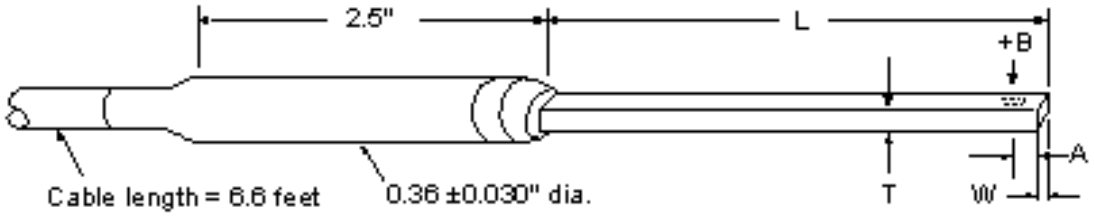
Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)		Contain Temperature Sensor
											Zero	Calibration	
HMMT-6J02-VR	2 ±0.125"	0.061" max.	0.180 ±0.005"	0.150 ±0.050"	0.040" dia. approx.	Alum.	DC to 800 Hz	HSE	±0.20% to 30 kG and ±0.25% 30–35 kG	0 °C to +75 °C	±0.09 Gauss per °C	±0.015% per °C	Yes
HMMT-6J04-VR*	4 ±0.125"												
HMMT-6J08-VR	8 ±0.125"												
HMMT-6J18-VR	18 ±0.25"												
HMNT-4E02-VR	2 ±0.125"	0.045" max.	0.150 ±0.005"			Fiber-glass Epoxy	DC to 20 kHz						
HMNT-4E04-VR*	4 ±0.125"												
HMMT-6J02-VF	2 ±0.125"	0.061" max.	0.180 ±0.005"			Alum.	DC to 400 Hz	HST-4	±0.10% to 30 kG and ±0.15% 30–35 kG		±0.13 Gauss per °C	–0.005% per °C	
HMMT-6J04-VF*	4 ±0.125"												
HMMT-6J08-VF	8 ±0.125"												
HMMT-6J18-VF	18 ±0.125"												
HMNT-4E02-VF	2 ±0.125"	0.045" max.	0.150 ±0.005"			Fiber-glass Epoxy	DC to 800 Hz						
HMNT-4E04-VF*	4 ±0.125"												
HMCT-3160-WN	61 ±1"	0.25 dia. ±0.010"		0.210 ±0.050"		Stainless Steel		HST-3	±2% to 100 kG	1.5 K to 350 K		±0.010% per °C	No

* One probe is included with the purchase of the Model 455. Model numbers shown in **bold** are the probes available to chose from.

Transverse.bmp

Figure 7-4. Definition of Lake Shore Transverse Probes

TANGENTIAL PROBE

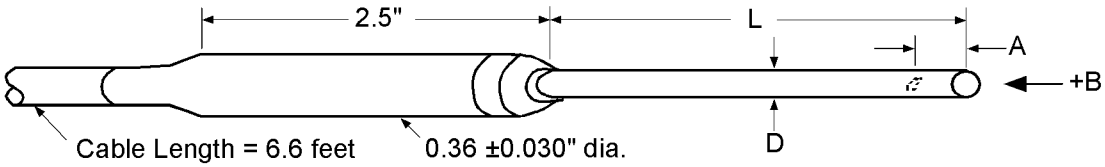


Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)		Contain Temperature Sensor
											Zero	Calibration	
HMNTAN-DQ02-TH	1.5" ±0.125"	0.125" max.	0.38" max	0.030" ±0.005"	0.020" dia. approx.	Plastic	DC to 400 Hz	HSE	±0.25 % to 20 kG	0 °C to +75 °C	±0.1 G/°C	–0.05%/°C	Yes

Tangential.eps

Figure 7-5. Definition of Lake Shore Tangential Probe

AXIAL PROBES



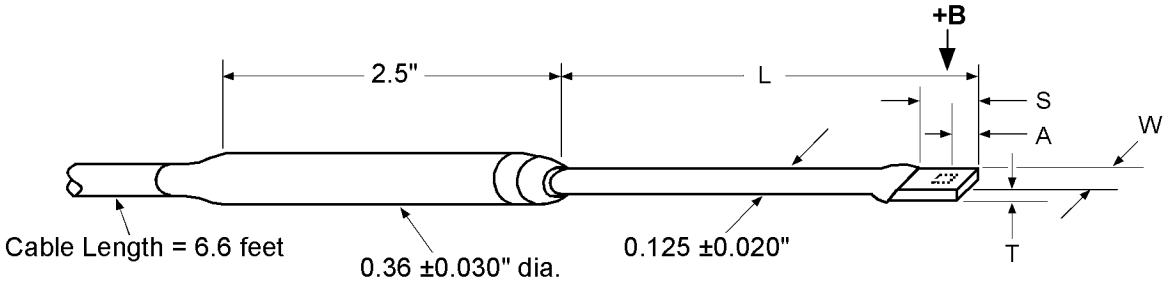
Model	L	D	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% Reading)	Op. Temp. Range	Temp. Coefficient (Max.)		Contain Temp. Sensor
										Zero	Calibration	
HMMA-0602-TH	2 ±0.125"	0.060 dia. +0.001 -0.003"	0.005 ±0.003"	0.020" dia. approx.	Alum.	DC to 400 Hz	HST-4	±0.25% to 10 kG	0 °C to 75 °C	±0.13 G per °C	±0.01% per °C	No
HMMA-0604-TH	4 ±0.125"											
HMMA-0608-TH	8 ±0.125"											
HMMA-0618-TH	18 ±0.125"											
HMMA-0802-UH	2 ±0.125"	0.080" dia. ±0.005"	0.010 ±0.005"			DC		±0.25% to 20 kG				
HMMA-0804-UH	4 ±0.125"											
HMMA-0808-UH	8 ±0.125"											
HMNA-1902-VR	2 ±0.125"	0.187 dia. ±0.005"	0.005 ±0.003"	0.030" dia. approx.	Fiber-glass Epoxy	DC to 20 kHz	HSE	±0.20% to 30 kG and ±0.25% 30–35 kG		±0.09 G per °C	±0.015% per °C	Yes
HMNA-1904-VR*	4 ±0.125"											
HMNA-1908-VR	8 ±0.125"											
HMMA-1802-VR	2 ±0.063"	0.180 dia. +0.002 -0.004"	0.015 ±0.005"		Alum.	DC to 10 kHz						
HMMA-1808-VR	8 ±0.125"											
HMMA-1818-VR	18 ±0.25"											
HMMA-1836-VR	36 ±0.25"											
HMMA-2502-VR*	2 ±0.063"	0.25 dia. ±0.006"										
HMMA-2508-VR	8 ±0.125"											
HMNA-1902-VF	2 ±0.125"	0.187 dia. ±0.005"	0.005 ±0.003"		Fiber-glass Epoxy	DC to 800 Hz	HST-4	±0.10% to 30 kG and ±0.15% 30–35 kG		±0.13 G per °C	–0.005% per °C	
HMNA-1904-VF*	4 ±0.125"											
HMNA-1908-VF	8 ±0.125"											
HMMA-1802-VF	2 ±0.063"	0.180 dia. +0.002 –0.004"	0.015 ±0.005"		Alum.	DC to 400 Hz						
HMMA-1808-VF	8 ±0.125"											
HMMA-1818-VF	18 ±0.25"											
HMMA-1836-VF	36 ±0.25"											
HMMA-2502-VF*	2 ±0.063"	0.25 dia. ±0.006"										
HMMA-2508-VF	8 ±0.125"											
HMMA-1808-WL	8 ±0.125"	0.180 dia. +0.002 –0.004"					HST-3	±1% to 100 kG				No
HMMA-2536-WL	36 ±0.25"	0.25 dia. ±0.006"				DC						
HMCA-2560-WN	60 ±0.50"	0.25 dia. ±0.006"	0.025 ±0.005"		Stainless Steel			±2% to 100 kG	1.5 K to 350 K		±0.010% per °C	

* One probe is included with the purchase of the Model 455. Model numbers shown in **bold** are the probes available to chose from.

Axial.bmp

Figure 7-6. Definition of Lake Shore Axial Probes

FLEXIBLE TRANSVERSE PROBES



This table is for L = 3 inches and S = 0.375 inch

Model No.	W	T	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of Reading)	Operating Temp. Range	Temperature Coefficient (maximum)		Contain Temperature Sensor
										Zero	Calibration	
HMFT-3E03-VR*	0.135" max	0.025" max	0.125" ±0.005"	0.040" dia. approx.	Flexible Tubing	DC to 20 kHz	HSE	±0.20% to 30 kG ±0.25% 30–35 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C	Yes
HMFT-3E03-VF*						DC to 800 Hz	HST-4	±0.10% to 30 kG ±0.15% 30–35 kG		±0.13 G/°C	–0.005%/°C	
HMFT-2903-VJ	0.085" max	0.020" max	0.065" ±0.005"	0.030" dia. approx.		DC to 20 kHz	HSE	±0.50% to 35 kG		±0.09 G/°C	±0.015%/°C	
HMFT-2903-VH						DC to 800 Hz	HST-4	±0.25% to 35 kG		±0.13 G/°C	–0.005%/°C	

This table is for L = 15 ±0.5 inches and S = 0.75 inch

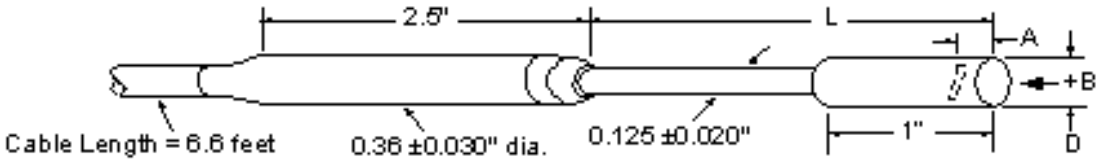
HMFT-4F15-VR	0.150" ±0.005"	0.045" max	0.150" ±0.050"	0.040" dia. approx.	Flexible Tubing & Epoxy Fiber-glass	DC to 20 kHz	HSE	±0.20% to 30 kG ±0.25% 30–35 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C	Yes
HMFT-4F15-VF						DC to 800 Hz	HST-4	±0.10% to 30 kG ±0.15% 30–35 kG		±0.13 G/°C	–0.005%/°C	

* One probe is included with the purchase of the Model 455. Model numbers shown in **bold** are the probes available to chose from.

Flexible_Transverse.bmp

Figure 7-7. Definition of Lake Shore Flexible Transverse Probes

FLEXIBLE AXIAL PROBE



Model No.	L	D	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temp. Range	Temperature Coefficient (max.)		Contain Temperature Sensor
										Zero	Calibration	
HMFA-1815-VR	15" ±0.5"	0.182" max	0.015" ±0.005"	0.030" dia. approx	Flexible Tubing & Aluminum	DC to 10 kHz	HSE	±0.20%to 30 kG ±0.25%30–35 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C	Yes

Flexible_Axial.eps

Figure 7-8. Definition of Lake Shore Flexible Axial Probe

7.4 PROBE ACCESSORIES

Additional accessories are available that may be desirable. A list of accessories available for magnetic systems is as follows:

Model	Description Of Accessories
HMPEC-XXX *or* **HMPEC-XXX-U**	**Probe Extension Cables**. Four cable lengths are available. Each extension cable contains an EEPROM for calibration data. To maintain probe accuracy, the probe and extension cable must be calibrated together at Lake Shore, however, probes may be matched to uncalibrated extension cables in the field. Refer to Section 5.1. The probe will exhibit its full accuracy if used without the extension cable. Part numbers and cables lengths are defined as follows: ***Calibrated*** / ***Uncalibrated*** / ***Description*** / ***Length*** **HMPEC-10** / **HMPEC-10-U** / Probe Extension Cable / 3 meters (10 feet) **HMPEC-25** / **HMPEC-25-U** / Probe Extension Cable / 8 meters (25 feet) **HMPEC-50** / **HMPEC-50-U** / Probe Extension Cable / 15 meters (50 feet) **HMPEC-100** / **HMPEC-100-U** / Probe Extension Cable / 30 meters (100 feet)
HMCBL-XX	**Hall Generator Cable Assembly**. The HMCBL Cable Assembly connects a discrete Hall generator to the Model 455 Gaussmeter. Refer to Section 7.5. Because of the many calibration intricacies, the user is responsible for measurement accuracy. Refer to Section 5.2 for programming instructions. **HMCBL-6** Hall Generator Cable Assembly – 2 meters (6 feet). **HMCBL-20** Hall Generator Cable Assembly – 6 meters (20 feet).
MH-XX	**Helmholtz Coils**. Provides stable low magnetic field when used with customer-supplied power supply. Often used to provide reference field to help check gaussmeter accuracy. Three coils are available as follows. Refer to Section 7.6. **MH-2.5** Helmholtz Coil, 2.5-inch inner diameter, field strength: ≈30 G @ 1 A, maximum continuous current: 2 A, coil resistance: ≈3 Ω. See Figure 7-13. **MH-6** Helmholtz Coil, 6-inch inner diameter, field strength: ≈25 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈10 Ω. See Figure 7-14. **MH-12** Helmholtz Coil. 12-inch inner diameter, field strength: ≈13 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈20 Ω. See Figure 7-15.
MRA-XXX **MRT-XXX**	**Reference Magnets**. High-quality reference magnets are available in transverse (flat) and axial (round) configurations. Refer to Section 7.7 and see Figure 7-16. **MRA-312-100** Axial Reference Magnet: 0.312 inch inside diameter, 100 G, 1% **MRA-312-200** Axial Reference Magnet: 0.312 inch inside diameter, 200 G, 1% **MRA-312-300** Axial Reference Magnet: 0.312 inch inside diameter, 300 G, 1% **MRA-312-500** Axial Reference Magnet: 0.312 inch inside diameter, 500 G, 1% **MRA-312-1K** Axial Reference Magnet: 0.312 inch inside diameter, 1 kG, 1% **MRA-312-2K** Axial Reference Magnet: 0.312 inch inside diameter, 2 kG, 1% **MRT-062-200** Transverse Reference Magnet: 0.062 inch gap, 200 G, 1% **MRT-062-500** Transverse Reference Magnet: 0.062 inch gap, 500 G, 1% **MRT-062-1K** Transverse Reference Magnet: 0.062 inch gap, 1 kG, 0.5% **MRT-062-2K** Transverse Reference Magnet: 0.062 inch gap, 2 kG, 0.5% **MRT-062-5K** Transverse Reference Magnet: 0.062 inch gap, 5 kG, 0.5% **MRT-062-10K** Transverse Reference Magnet: 0.062 inch gap, 10 kG, 5% **MRT-343-50** Transverse Reference Magnet: 0.343 inch gap, 50 G, 1% **MRT-343-100** Transverse Reference Magnet: 0.343 inch gap, 100 G, 1%

7.5 HALL GENERATOR

Lake Shore sells a series of bare Hall generators for applications that are unsuitable for standard probe configurations. This section describes the handling, wiring and specifications of the bare Hall generators available from Lake Shore. Please consult the factory for availability of bare Hall generator types not detailed in this section.

7.5.1 Hall Generator Handling

CAUTION: Care must be exercised when handling the Hall generator. The device is very fragile. Stressing the Hall sensor can alter its output. Any excess force can easily break the Hall generator. Broken Hall generators are not repairable.

Hall Generators are very fragile and require delicate handling. The ceramic substrate used to produce the Hall sensor is very brittle. Use the leads to move the Hall generator. Do not handle the substrate. The strength of the lead-to-substrate bond is about 7 ounces, so avoid tension on the leads and especially avoid bending them close to the substrate. The Hall Generator is also susceptible to bending and thermal stresses.

7.5.2 Hall Generator Lead Wires

Lake Shore Hall generators (except Models HGCA-3020 and HGCT-3020) have 34 AWG solid copper lead wire with poly-nylon insulation and have the following color coded lead configuration.

Red = $+I_C$
Green = $-I_C$
} Input (Control Current)

Blue = $+V_H$
Clear = $-V_H$
} Output (Hall Voltage)

The Model HGCA-3020 and HGCT-3020 Hall generators have 34 AWG stranded copper lead wire with Teflon® insulation and have the following color coded lead configuration:

Red = $+I_C$
Black = $-I_C$
} Input (Control Current)

Blue = $+V_H$
Yellow = $-V_H$
} Output (Hall Voltage)

7.5.3 Using a Hall Generator with the Model 455

Connecting a Hall generator to the Model 455 requires a Lake Shore Model HMCBL-6 or -20 Cable Assembly (sold separately). The cable has a 15 pin D-sub connector on one end and four leads on the other. The 4 leads, illustrated in Figure 7-9, correspond to the 4 leads on the Hall generators given in Section 7.5.2.

Each Hall generator purchased from Lake Shore will come with a nominal field sensitivity value. However, we recommend that the customer always check accuracy against a reference field rather than use the sensitivity value sent with the bare Hall generator. Because Lake Shore has no control of the conditions beyond the cable, the customer must accept responsibility for accuracy and compatibility.

In cryogenic applications, Manganin lead wire is frequently used because of its thermal conductivity properties. Manganin wire is not usually acceptable for connection to a Hall generator because the resistance of Manganin wire is often too high. The gaussmeter current source is limited in compliance voltage. The Model 455 should not drive a load (Hall generator, wires in cryostat, and probe cable) greater than 50 Ω. In fact, for best performance, the load should be less than 30 Ω. In cryogenic applications, Hall generators are normally connected using twisted pairs of copper wire such as 34 gauge, Teflon insulated.

7.5.4 Attachment To A User Programmable Cable

The Model HMCBL-XX has a 15 pin D-sub connector on one end for direct attachment to the PROBE INPUT connection on the back panel of the Model 455 Gaussmeter. Four tinned wires are provided for connection to the Hall Generator. The leads may be soldered directly to these wires. The cable comes in two lengths: the HMCBL-6 is 2 meters (6 feet) and the HMCBL-20 is 6 meters (20 feet).

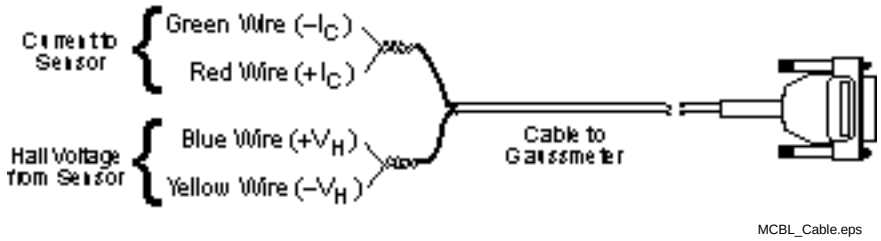


Figure 7-9. Model HMCBL-XX User Programmable Cable Accessory

CAUTION: The Hall Generator should be isolated from all line voltages (or voltages referenced to earth ground). *If not, damage to the Model 455 Gaussmeter is almost a certainty.*

IMPORTANT:

Refer to Section 7.5.5 for a partial list of compatible Hall generators manufactured by Lake Shore. Once connections are made, refer to Section 5.2 for instructions on programming parameters into the internal EPROM.

7.5.5 Hall Generator Specifications

This section covers three types of Hall generators available from Lake Shore: HGCA & HGCT Series Cryogenic Hall generators (Figures 7-10 and 7-11) with specifications (Table 7-1), HGA Series Axial Hall generators (Figure 7-11) with specifications (Table 7-2), and HGT Series Transverse Hall generators (Figure 7-12) with specifications (Table 7-3).

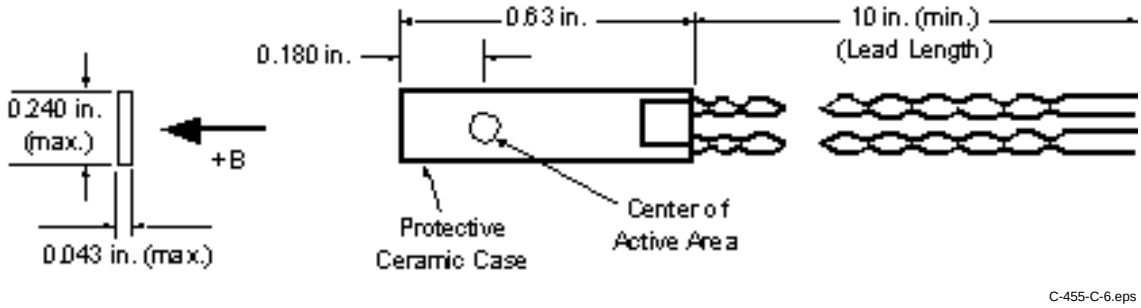


Figure 7-10. Transverse Hall Generator HGT-3010, HGT-3030, and HGCT-3020 Dimensions

Table 7-1. Cryogenic Hall Generator Specifications

Cryogenic	HGCA-3020	HGCT-3020
Description	Cryogenic axial; phenolic package	Cryogenic transverse; ceramic package
Active area (approximate)	0.030 inch diameter circle	0.040 inch diameter circle
Input resistance (approximate)	1 ohm	1 ohm
Output resistance (approximate)	1 ohm	1 ohm
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	0.55 to 1.05 mV/kG
Maximum linearity error (sensitivity vs. field)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)
Zero field offset voltage (I_C = nominal control current)	±200 µV (max.)	±200 µV (max.)
Operating temperature range	1.5 K to 375 K	1.5 K to 375 K
Mean temperature coefficient of magnetic sensitivity	±0.01%/K (approx.)	±0.01%/K (approx.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/K (max.)	±0.4 µV/K (max.)
Mean temperature coefficient of resistance	±0.6%/K (max.)	±0.6%/K (max.)
Leads	34 AWG copper w/Teflon insulation	34 AWG copper w/Teflon insulation

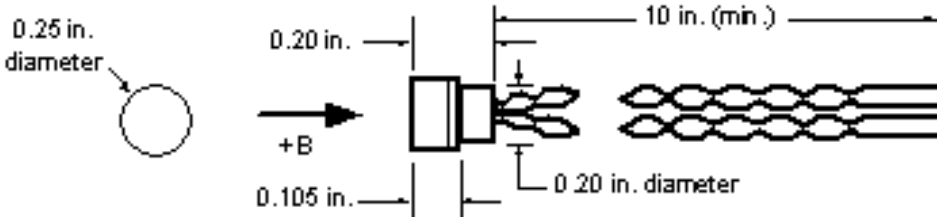


Figure 7-11. Axial Hall Generator HGA-3010, HGA-3030, and HGCA-3020 Dimensions

Table 7-2. Axial Hall Generator Specifications

Axial	HGA-3010	HGA-3030
Description	Instrumentation quality axial; low temperature coefficient; phenolic package	Instrumentation quality axial; phenolic package
Active area (approximate)	0.030 inch diameter circle	0.030 inch diameter circle
Input resistance (approximate)	1 ohm	2 ohms
Output resistance (approximate)	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1% RDG (–30 to +30 kG) ±1.5% RDG (–100 to +100 kG)	±0.30% RDG (–10 to +10 kG) ±1.25% RDG (–30 to +30 kG)
Zero field offset voltage (I_C = nominal control current)	±50 µV (max.)	±75 µV (max.)
Operating temperature range	–40 to +100 °C	–40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	±0.005%/°C (max.)	–0.04%/°C (max.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/°C (max.)	±0.3 µV/°C (max.)
Mean temperature coefficient of resistance	+0.15%/°C (approx.)	+0.18%/°C (approx.)
Leads	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

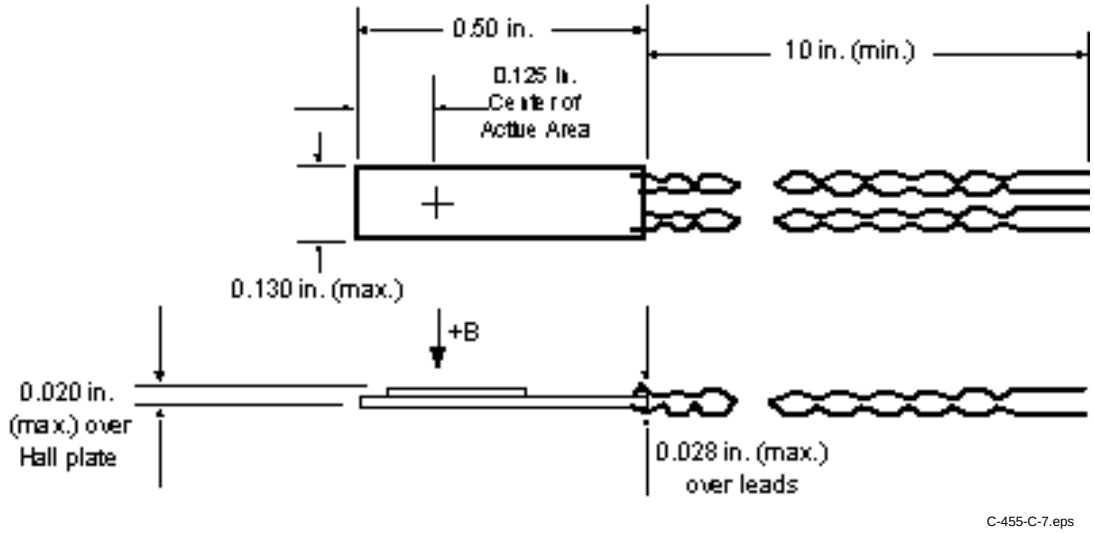


Figure 7-12. Transverse Hall Generator HGT-1010 Dimensions

Table 7-3. Transverse Hall Generator Specifications

Transverse	HGT-1010	HGT-3010	HGT-3030
Description	General purpose transverse; 0.020 inch thick	Instrumentation quality transverse; low temperature coefficient; ceramic package	Instrumentation quality transverse ceramic package
Active area (approximate)	0.040 inch diameter circle	0.040 inch diameter circle	0.040 inch diameter circle
Input resistance (approx.)	2 ohms	1 ohm	2 ohms
Output resistance (approx.)	2 ohms	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA	100 mA
Maximum continuous current (non-heat sinked)	250 mA	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	7.5 to 12.5 mV/kG	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1.0% RDG (-10 to 10 kG)	±1% RDG (-30 to 30 kG) ±1.5% RDG (-100 to 100 kG)	±0.30% RDG (-10 to 10 kG) ±1.25% RDG (-30 to 30 kG)
Zero field offset voltage (I_C = nominal control current)	±100 µV max.	±50 µV max.	±75 µV max.
Operating temperature range	–40 to +100 °C	–40 to +100 °C	–40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	–0.08%/°C max.	±0.005%/°C max.	–0.04%/°C max.
Mean temperature coefficient of offset (I_C = nominal control current)	±1 µV/°C max.)	±0.4 µV/°C max.	±0.3 µV/°C
Mean temperature coefficient of resistance	±0.18%/°C approx.	±0.15%/°C approx.	+0.18%/°C approx.
Leads	34 AWG copper with poly-nylon insulation.	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

7.6 HELMHOLTZ COIL LOW FIELD STANDARDS

Lake Shore offers three Helmholtz coils: 2.5-, 6-, and 12-inch diameter. Check the Lake Shore website for any recent additions to this line.

These coils are accurately calibrated using field standards maintained at Lake Shore. Most standards are traceable to physical standards such as a coil of carefully controlled dimensions, or in some cases, to proton resonance. The field strengths are measured on the basis of the field generated by a current through the coil.

When combined with a customer-supplied power supply, these coils can be used as low-field reference magnets to compliment our set of standard reference magnets (defined in Section 7.7). To achieve maximum field, the power supply must be capable of 2 A output and a constant-current mode is recommended.

	MH-2.5	**MH-6**	**MH-12**
Inside Diameter	2.5 inches	6 inches	12 inches
Field Accuracy	±0.5%		
Field Strength	≈30 G @ 1 A	≈25 G @ 1 A	≈13 G @ 1 A
Field Homogeneity	0.5% within a cylindrical volume 0.75" long, 0.75" diameter, located at center of coil	0.5% within a cylindrical volume 1.6" long, 1.6" diameter, located at center of coil	0.5% within a cylindrical volume 3.2" long, 3.2" diameter, located at center of coil
Coil Resistance/Inductance	≈3 Ω/6.3 mH	≈10 Ω/36 mH	≈20 Ω/93 mH
Maximum Continuous Current	2 A DC or AC RMS		
Operating Temperature Range	10 to 40 °C (50 to 104 °F)		

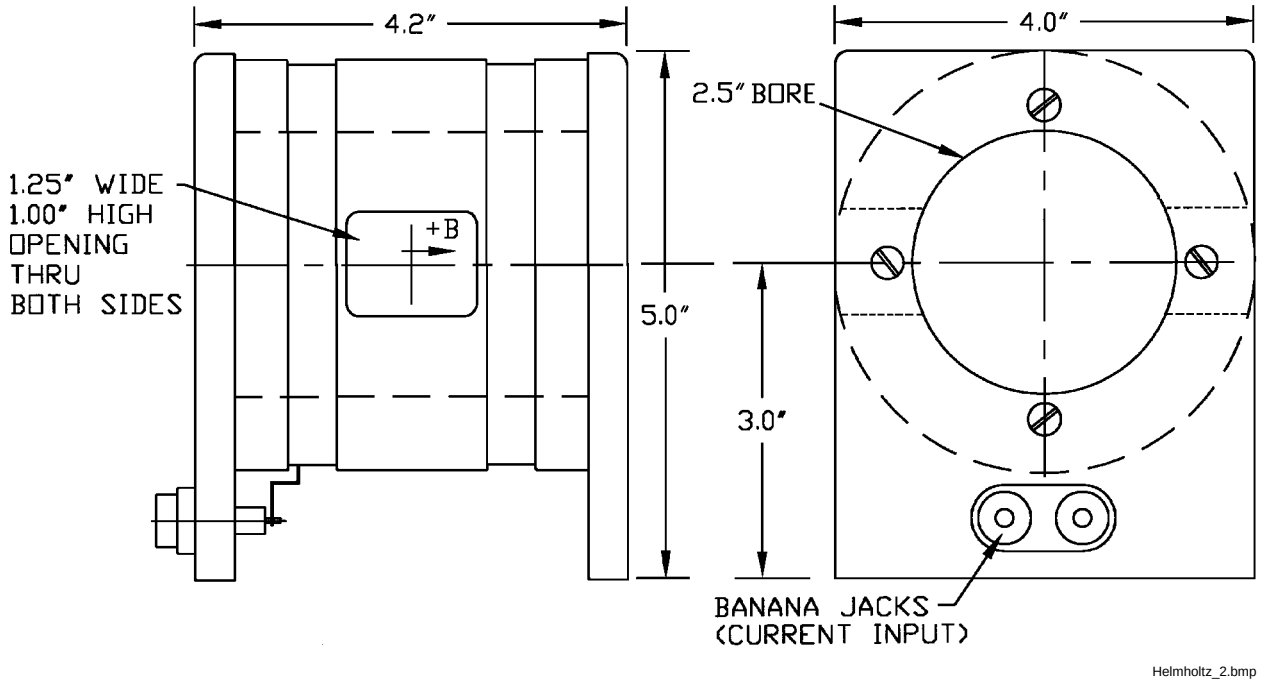


Figure 7-13. Model MH-2.5 Helmholtz Coil

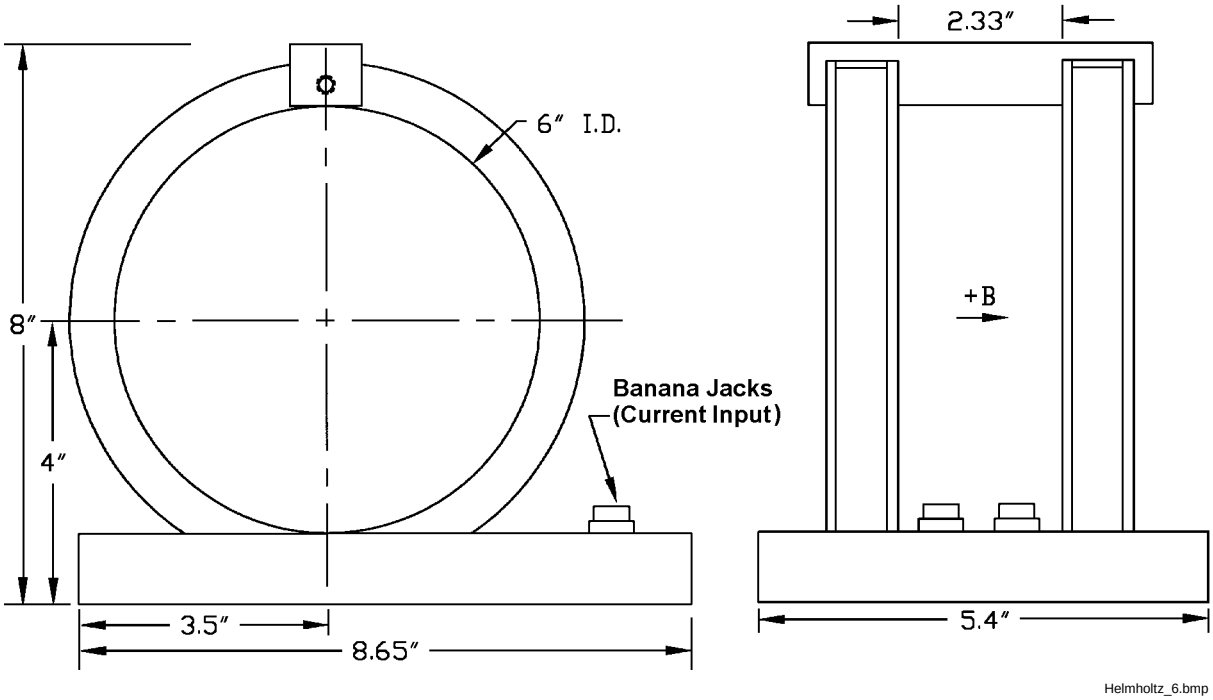


Figure 7-14. Model MH-6 Helmholtz Coil

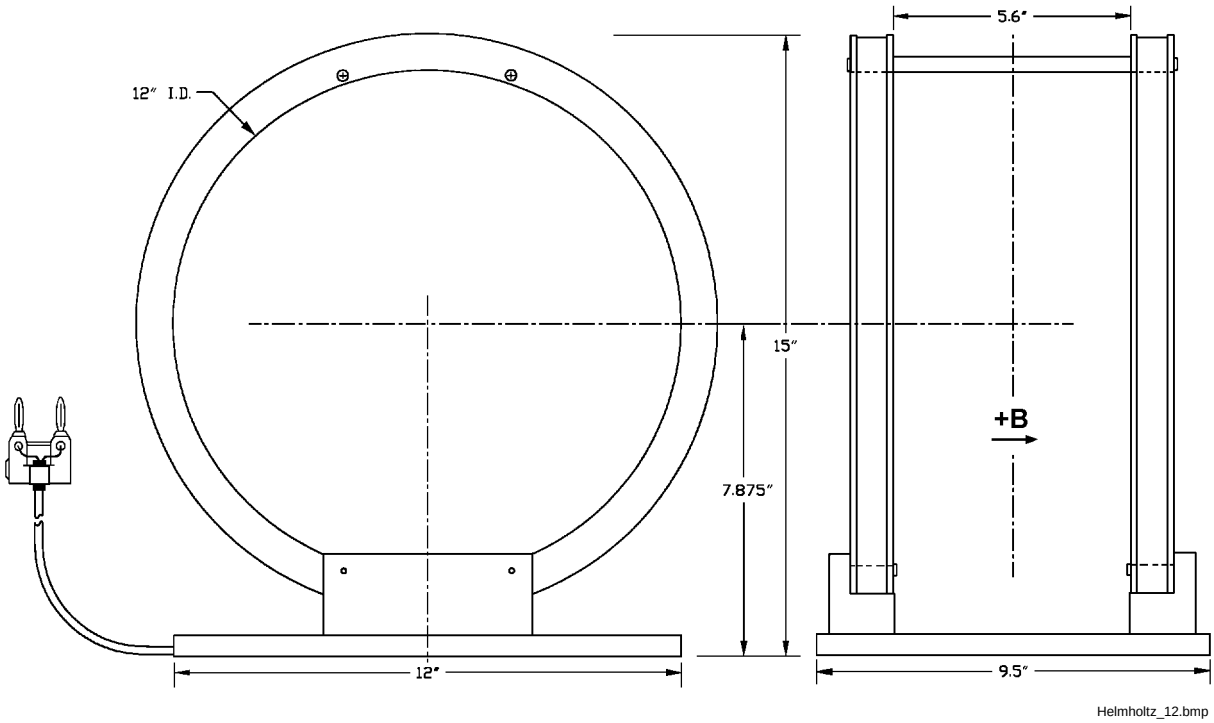


Figure 7-15. Model MH-12 Helmholtz Coil

7.7 REFERENCE MAGNETS

Magnetic reference standards containing highly stable permanent magnets have been in use for many years. The highest quality units are usually shielded from external magnetic effects and use Alnico V or VI magnets for long-term stability. They are supplied in both transverse (flat) and axial configurations.

Typical transverse reference magnets are usually stabilized for use at ambient temperatures between 0−50 °C and have nominal temperature coefficients of about –0.02%/°C. Because the temperature coefficient is negative, the field strength will be reduced as the temperature rises. Since these references are temperature cycled during manufacture, their change with temperature is predictable and retraceable; they will always return to a known value at any specific ambient temperature.

The high-permeability shell which surrounds the reference magnet serves two function: (1) it shields the magnet from external field, and (2) serves as the flux return path. Physical damage to the outer shell can cause a permanent change in the gap flux density. Reference magnets should not be dropped or physically abused. Magnets of this type can have magnetic reference values ranging from 100 G to 20 kG, but the most widely-used value is 1 kG. Reference magnet accuracy is typically ±0.5%, except for magnets of 200 G or less; for these magnets, the limit of error is generally ±1%. The reference magnet gap is nominally 0.060 inch but may range from 0.040 to 0.250 inch for special units. The usable "plateau" in the reference gap generally encompasses an area of about 0.5 square inches.

In reference magnets used for axial field probes, Alnico V or VI is the usual magnet material, charged to saturation and stabilized down to a particular value. The same temperature coefficients hold true as in the transverse probe and the same care in handling must be observed. This assembly uses concentric mu-metal shield cans to protect the magnet from the effects of external magnetic field. Axial reference magnets are available in values up to 2 kG, with 500 G being the most widely-used value.

When a probe is inserted completely through the access guide, three distinct magnetic peaks will be observed on the gaussmeter. One peak occurs as the probe enters the magnet, a second (and greater) peak is observed as the midpoint is reached, and a third (smaller) peak is read as the probe leaves the magnet. The calibration point is the largest reading in the midpoint area. Its amplitude will be approximately twice that of the readings that occur where the probe enters or leaves the magnet.

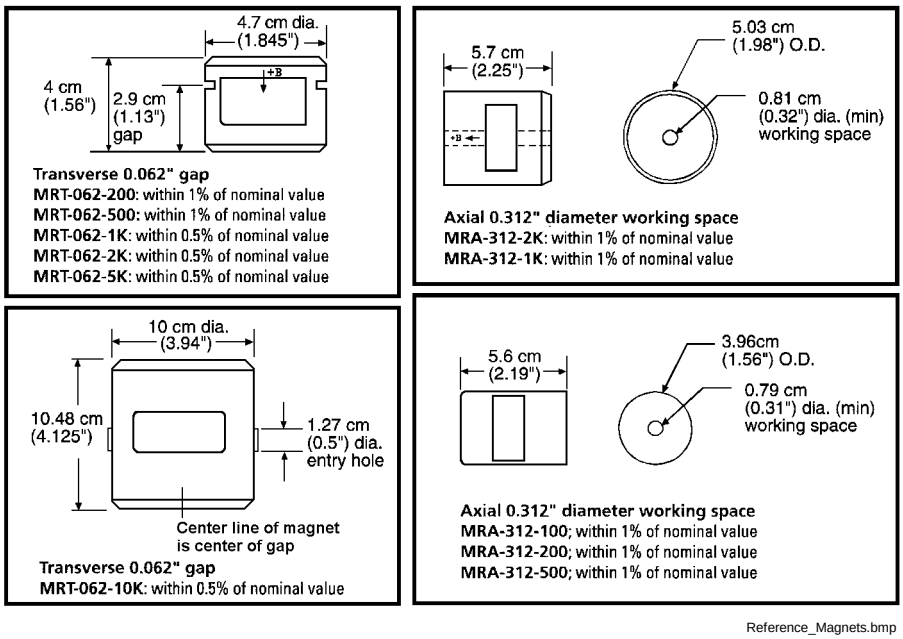


Figure 7-16. Lake Shore Reference Magnets

7.8 ZERO GAUSS CHAMBER

NOTE: Use care to ensure the Zero Gauss Chamber does not become magnetized. Using a magnetized chamber to zero a probe can lead to erroneous field readings. It is a good practice to periodically degauss the chamber. If no professional degausser is available, a bulk tape degausser (Verity VS250, Data Devices PF211, or equivalent) may be used.

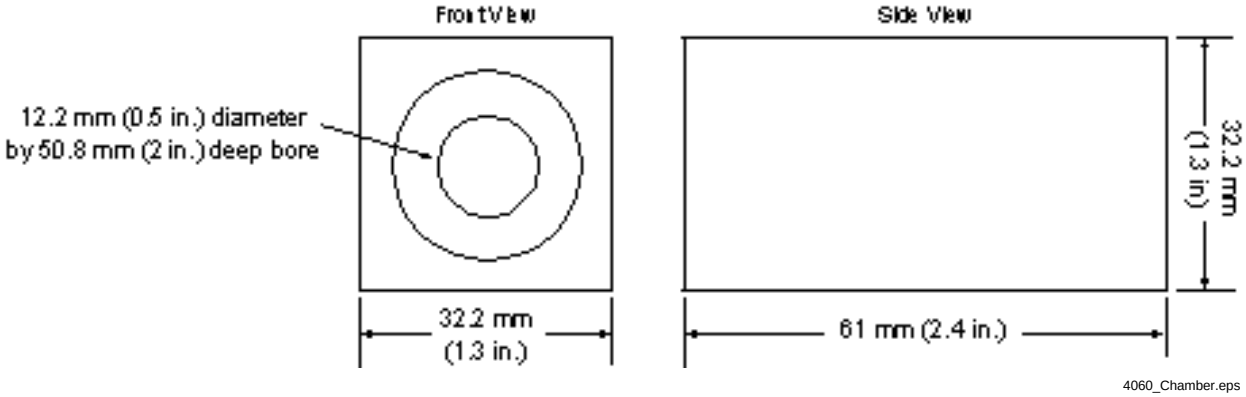


Figure 7-17. Model 4060 Zero Gauss Chamber

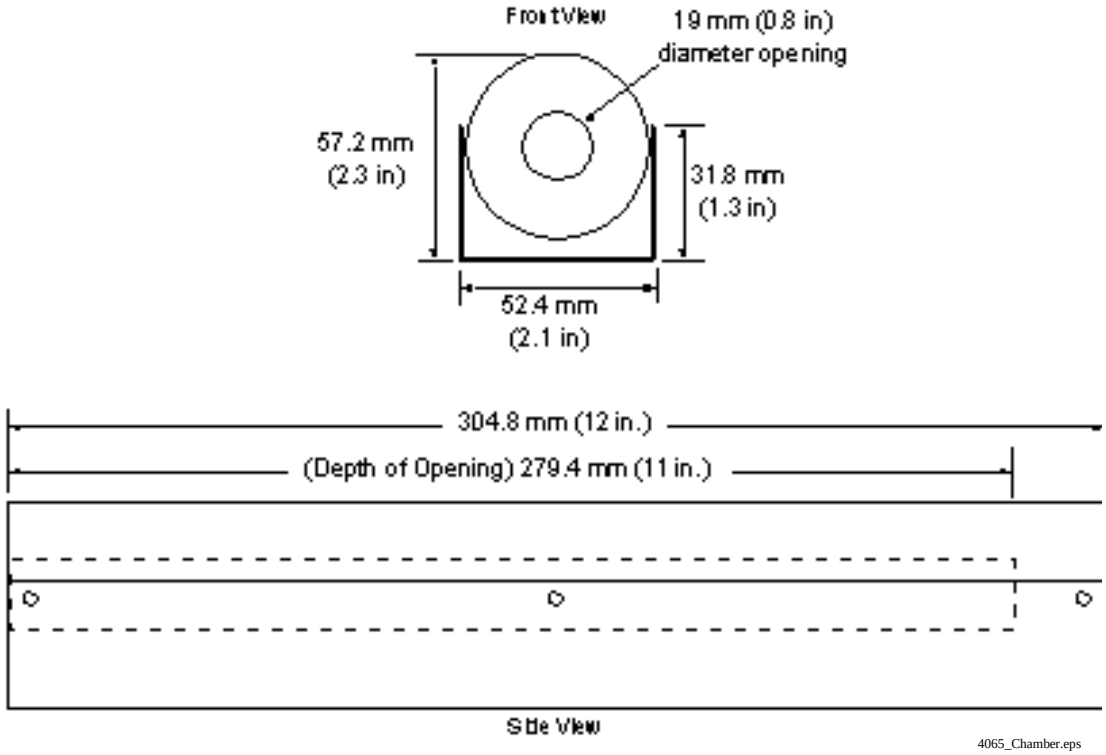


Figure 7-18. Model 4065 Large Zero Gauss Chamber

CHAPTER 8

SERVICE

8.0 GENERAL

This chapter provides basic service information for the Model 455 Gaussmeter. Customer service of the product is limited to the information presented in this chapter. Factory trained service personnel should be consulted if the instrument requires repair.

8.1 CONTACTING LAKE SHORE CRYOTRONICS

If a Lake Shore product was purchased through a dealer or representative, please use that resource for prompt sales or service information. When contacting Lake Shore directly, please specify the name of a department if do not know the name of an individual. Questions regarding product applications, price, availability and shipments should be directed to sales. Questions regarding instrument calibration or repair should be directed to instrument service. **Do not return a product to Lake Shore without an RGA number**. Refer to Section 8.2. Contact information may change periodically but current contact information can always be found on the Lake Shore web site: www.lakeshore.com.

Mailing Address:	Lake Shore Cryotronics, Inc. Instrument Service Department 575 McCorkle Blvd. Westerville, OH USA 43082-8888	
E-mail Address:	sales@lakeshore.com service@lakeshore.com	Sales Instrument Service
Telephone:	614-891-2244 614-891-2243 ext. 131	Sales Instrument Service
Fax:	614-818-1600 614-818-1609	Sales Instrument Service

When contacting Lake Shore please provide your name and complete contact information including e-mail address if possible. It is often helpful to include the instrument model number and serial number (located on the rear panel of the instrument) as well as the firmware revision information as described in Section 4.14.

8.2 RETURNING PRODUCTS TO LAKE SHORE

If it is necessary to return the Model 455 or accessories for recalibration, repair or replacement, a Return Goods Authorization (**RGA**) number must be obtained from a factory representative or from the Lake Shore web site. **Do not return a product to Lake Shore without an RGA number**. The following information must be provided to Lake Shore in order to obtain an RGA number.

1. Instrument model and serial number.
2. User name, company, address, phone number, and e-mail address.
3. Malfunction symptoms.
4. Description of the system in which the product is used.

If possible, the original packing material should be retained for reshipment. If not available, a minimum of three inches of shock adsorbent packing material should be placed snugly on all sides of the instrument in a sturdy corrugated cardboard box. The RGA number should be included in the mailing label or written prominently on the outside of the box. A copy of the customer contact information and RGA number should be included inside the box. Consult Lake Shore with questions regarding shipping and packing instructions.

8.3 FUSE DRAWER

The fuse drawer supplied with the Model 455 holds the instrument line fuses and line voltage selection module. The drawer holds two 5 × 20 mm time delay fuses. It requires two good fuses of the same rating to operate safely. Fuse ratings are different for different line voltages. Refer to Section 8.5 for details.

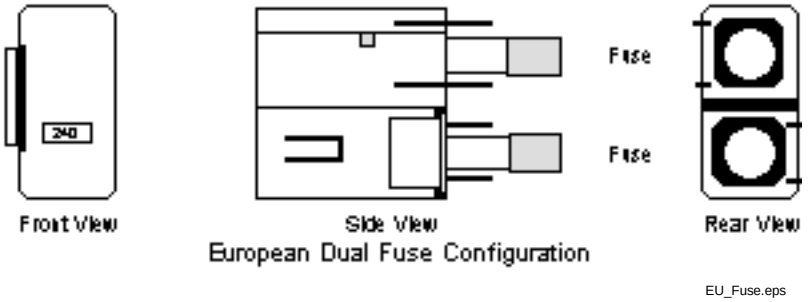


Figure 8-1. Fuse Drawer

8.4 LINE VOLTAGE SELECTION

Use the following procedure to change the instrument line voltage selector. Verify the fuse value whenever line voltage is changed.

WARNING: To avoid potentially lethal shocks, turn off controller and disconnect it from AC power before performing this procedure.

1. Identify the line input assembly on the instrument rear panel. See Figure 8-2.
2. Turn the line power switch OFF (**O**).
3. Remove the instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Slide out the removable plastic fuse holder from the drawer.
6. Rotate the fuse holder until the proper voltage indicator shows through the window.
7. Verify the proper fuse value.
8. Re-assemble the line input assembly in the reverse order.
9. Verify the voltage indicator in the window of the line input assembly.
10. Connect the instrument power cord.
11. Turn the line power switch On (**I**).

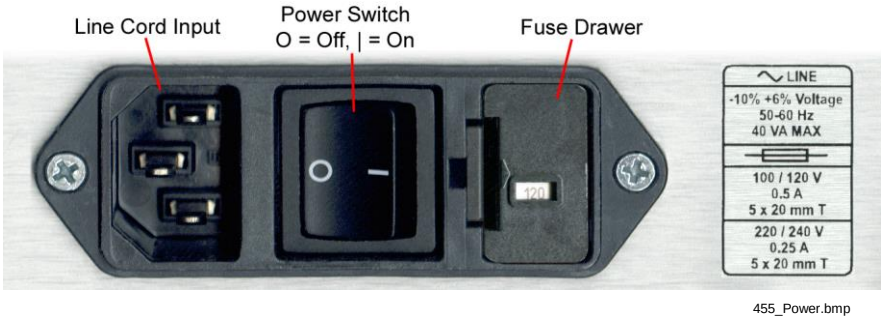


Figure 8-2. Power Fuse Access

8.5 FUSE REPLACEMENT

Use the following procedure to remove and replace the line fuses.

WARNING: To avoid potentially lethal shocks, turn off controller and disconnect it from AC power before performing these procedures.

CAUTION: For continued protection against fire hazard, replace only with the same fuse type and rating specified for the line for the line voltage selected.

Fuse Replacement (Continued)

NOTE: Test fuse with an ohmmeter. Do not rely on visual inspection of fuse.

1. Locate line input assembly on the instrument rear panel. See Figure 8-2.
2. Turn power switch Off (**O**).
3. Remove instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuses.
5. Remove and discard both existing fuses. Replace with proper Slow-Blow (time-delay) fuse ratings as follows:

100/120V	0.5A	5×20 mm T
220/240V	0.25A	5×20 mm T

6. Re-assemble line input assembly in reverse order.
7. Verify voltage indicator in the line input assembly window.
8. Connect instrument power cord.
9. Turn power switch On (**I**).

8.6 ERROR MESSAGES

The following messages appear on the instrument display when it identifies a problem during operation. The messages are divided into three groups. Instrument hardware messages are related to the instruments internal circuits or non-volatile memory. If one of these messages persists after power is cycled the instrument requires repair or recalibration. Measurement messages are most often associated with over field conditions caused by an improperly selected field range or excessive noise on the measurement leads, or a missing or illegal probe. If these messages persist after proper configuration, the instrument may require repair. Illegal operation messages remind the operator when a feature is locked out or the instrument is not configured to support a feature.

Instrument Hardware

Defective RAM	Internal RAM is defective and must be replaced
Invalid EEPROM	EEPROM contents are corrupt and parameter values will be reset to default. Reoccurrence may indicate defective EEPROM. Calibration may be affected.
Input Not Responding	Internal processor communication has failed.
Invalid Calibration	Instrument has not been calibrated or calibration memory has been corrupted. Recalibration is required for accurate measurements. Press the Escape and Enter keys simultaneously to clear the message. The instrument can still be used but it may not be operating within specifications.

Measurement

No Probe	There is no probe attached or the attached probe is damaged.
Invalid Probe	The detected probe is not recognized as a valid Model 455 probe. Press Enter to continue.
Incompatible Probe	A previous generation probe has been attached. Press Enter to continue. Measurement uses only nominal probe sensitivity. Accuracy not guaranteed.
OL	The measured field is larger than the range. Increase the measurement range. Check probe zero. Probe may be damaged.
SUNDER	The temperature sensor reading is less than the minimum temperature table entry.
SOVER	The temperature sensor reading is greater than the maximum temperature table entry.

Illegal Operation

LOCKED	A key operation was attempted with the keypad locked.
Max Not Available With Peak	Max Hold and Peak do not operate together.
Invalid MPEC Cable	Improper cable attached during the HMPEC programming process.
Invalid MCBL Cable	Improper cable attached during the HMCBL programming process.

8.7 ELECTROSTATIC DISCHARGE

Electrostatic Discharge (ESD) may damage electronic parts, assemblies, and equipment. ESD is a transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. The low-energy source that most commonly destroys Electrostatic Discharge Sensitive (ESDS) devices is the human body, which generates and retains static electricity. Simply walking across a carpet in low humidity may generate up to 35,000 volts of static electricity.

Current technology trends toward greater complexity, increased packaging density, and thinner dielectrics between active elements, which results in electronic devices with even more ESD sensitivity. Some electronic parts are more ESDS than others. ESD levels of only a few hundred volts may damage electronic components such as semiconductors, thick and thin film resistors, and piezoelectric crystals during testing, handling, repair, or assembly. Discharge voltages below 4000 volts cannot be seen, felt, or heard.

8.7.1 Identification of Electrostatic Discharge Sensitive Components

The following are various industry symbols used to label components as ESDS.

8.7.2 Handling Electrostatic Discharge Sensitive Components

Observe all precautions necessary to prevent damage to ESDS components before attempting installation. Bring the device and everything that contacts it to ground potential by providing a conductive surface and discharge paths. As a minimum, observe these precautions:

1. De-energize or disconnect all power and signal sources and loads used with unit.
2. Place unit on a grounded conductive work surface.
3. Ground technician through a conductive wrist strap (or other device) using 1 MΩ series resistor to protect operator.
4. Ground any tools, such as soldering equipment, that will contact unit. Contact with operator's hands provides a sufficient ground for tools that are otherwise electrically isolated.
5. Place ESDS devices and assemblies removed from a unit on a conductive work surface or in a conductive container. An operator inserting or removing a device or assembly from a container must maintain contact with a conductive portion of the container. Use only plastic bags approved for storage of ESD material.
6. Do not handle ESDS devices unnecessarily or remove from the packages until actually used or tested.

8.8 ENCLOSURE TOP REMOVAL AND REPLACEMENT

WARNING: To avoid potentially lethal shocks, turn off controller and disconnect it from AC power line before performing this procedure. Only qualified personnel should perform this procedure.

REMOVAL

1. Set power switch to Off (**O**) and disconnect power cord from rear of unit.
2. If attached, remove 19-inch rack mounting brackets.
3. Use 5/64 hex key to remove 4 screws attaching top panel to unit.
4. Use 5/64 hex key to loosen 2 screws attaching rear bottom panel to unit.
5. Carefully remove the back bezel by sliding it straight back away from the unit.
6. Slide the top panel back and remove it from the unit.

INSTALLATION

1. Slide the top panel forward in the track provided on each side of the unit.
2. Carefully replace the back bezel by sliding it straight into the unit.
3. Use 5/64 hex key to install 4 screws attaching top panel to unit.
4. Use 5/64 hex key to tighten 2 screws attaching rear bottom panel to unit.
5. If required, reattach 19-inch rack mounting brackets.
6. Connect power cord to rear of unit and set power switch to On (**I**).

8.9 FIRMWARE REPLACEMENT

There is one integrated circuit (IC) that may potentially require replacement. See Figure 8-3 for the IC location.

- Main Firmware Erasable Programmable Read Only Memory (EPROM) (U16) – Contains the user interface software. Has a sticker on top labeled "M455MF.HEX" and a date.

Use the following procedure to replace this IC.

1. Follow the top of enclosure *REMOVAL* procedure in Section 8.8.
2. Locate the IC on the main circuit board. See Figure 8-3. Note orientation of existing IC.

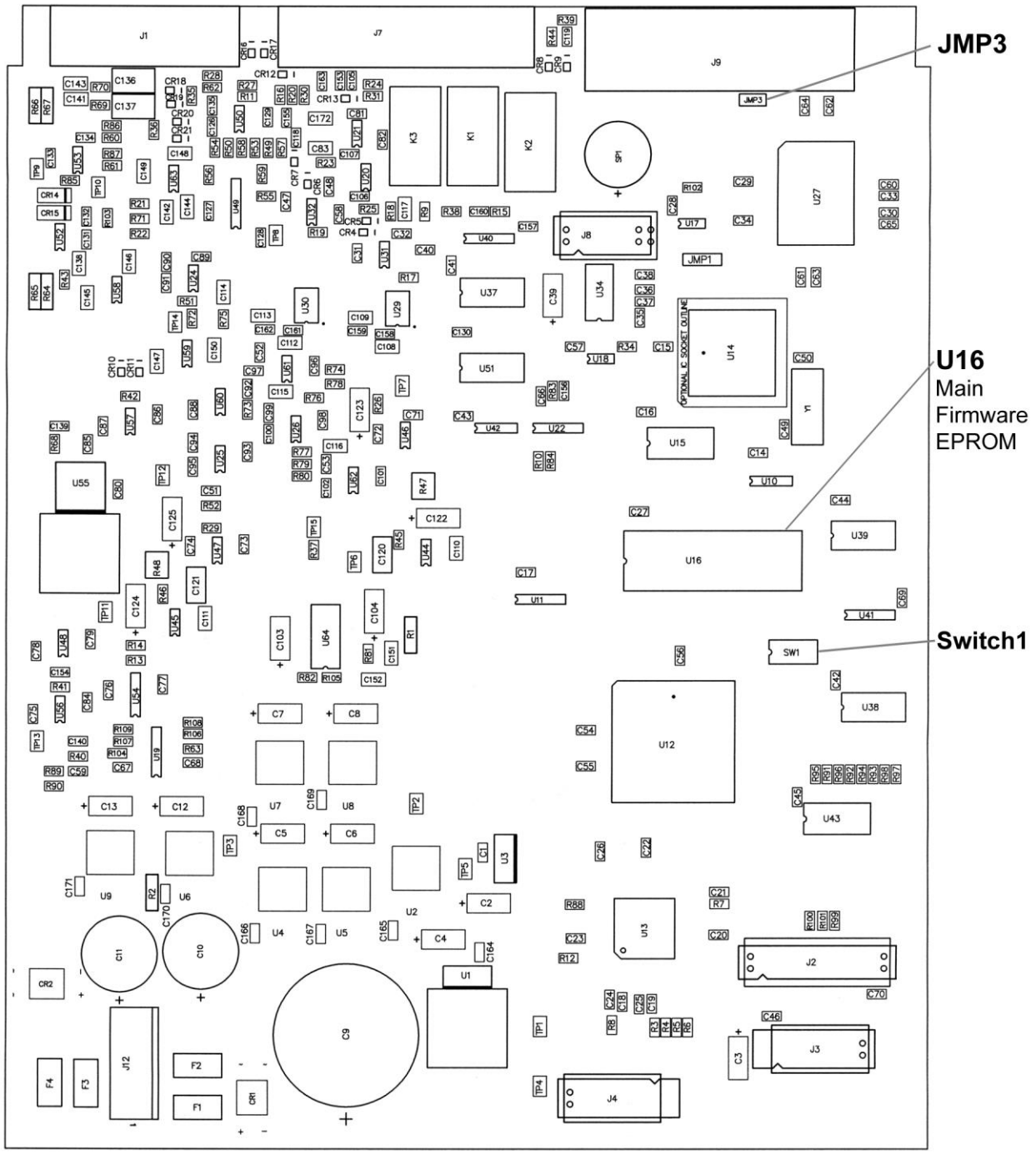
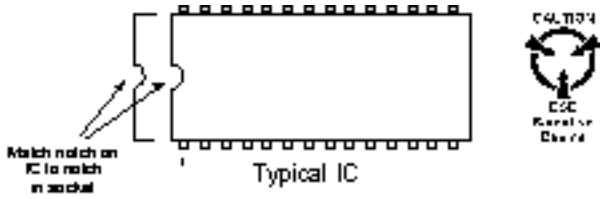


Figure 8-3. Location Of Important Internal Components

Firmware Replacement (Continued)

CAUTION: The ICs are Electrostatic Discharge Sensitive (ESDS) devices. Wear shock-proof wrist straps (resistor limited to <5 mA) to prevent injury to service personnel and to avoid inducing an Electrostatic Discharge (ESD) into the device.

3. Use IC puller to remove existing IC from the socket.
4. Noting orientation of new IC, use an IC insertion tool to place new device into socket.

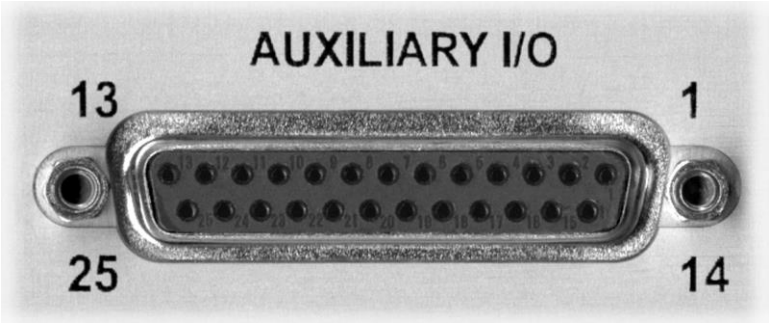


Eprom.eps

5. Follow the top of enclosure *INSTALLATION* procedure in Section 8.8.

8.10 CONNECTOR AND CABLE DEFINITIONS

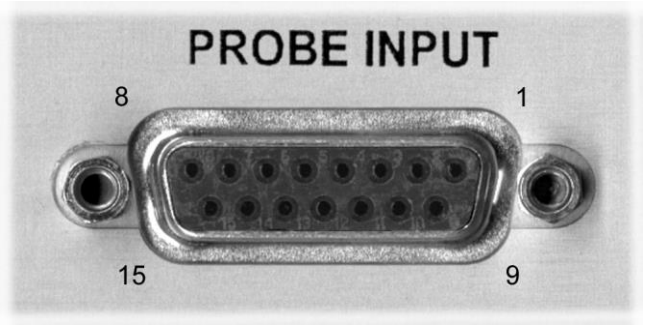
The AUXILIARY I/O, PROBE INPUT, SERIAL I/O (DTE), and IEEE-488 INTERFACE connectors are defined in Figures 8-4 thru 8-7.



Auxiliary_IO.bmp

Pin	*Description*	*Pin*	*Description*
1	Analog Out 1	14	Ground
2	Analog Out 2	15	Ground
3	Analog Out 3	16	Ground
4	*No Connection*	17	*No Connection*
5	Internal Use Only	18	*No Connection*
6	Internal Use Only	19	*No Connection*
7	*No Connection*	20	*No Connection*
8	Relay 1 NO	21	*No Connection*
9	Relay 1 COM	22	*No Connection*
10	Relay 1 NC	23	*No Connection*
11	Relay 2 NO	24	*No Connection*
12	Relay 2 COM	25	*No Connection*
13	Relay 2 NC		

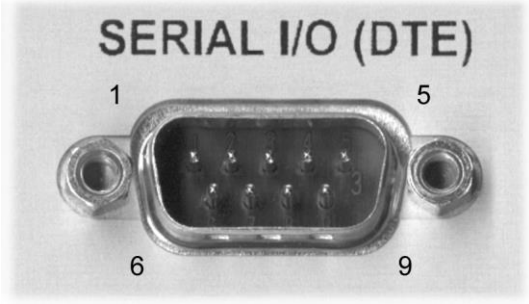
Figure 8-4. AUXILIARY I/O Connector Details



Probe_Input.bmp

Pin	*Description*	*Pin*	*Description*
1	V input +	9	V input –
2	No Connection	10	No Connection
3	V temp +	11	EEPROM GND
4	I temp +	12	EEPROM VCC
5	I temp –	13	EEPROM CLK
6	V temp –	14	EEPROM DATA
7	No Connection	15	I hall –
8	I hall +		

Figure 8-5. PROBE INPUT Connector Details



Serial_IO.bmp

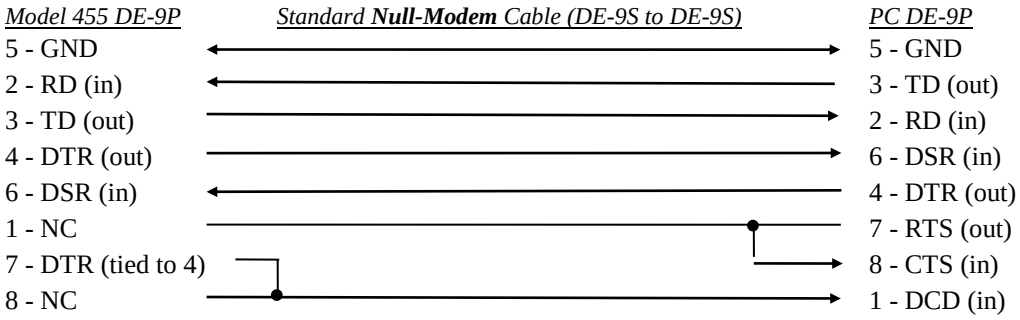
Model 455 Gaussmeter		**Typical Computers**			
SERIAL I/O (DTE)		**DB-25P (DTE)**		**DE-9P (DTE)**	
Pin	**Description**	**Pin**	**Description**	**Pin**	**Description**
1	No Connection	2	TD (out)	1	DCD (in)
2	Receive Data (RD in)	3	RD (in)	2	RD (in)
3	Transmit Data (TD out)	4	RTS (out)	3	TD (out)
4	Data Terminal Ready (DTR out)	5	CTS (in)	4	DTR (out)
5	Ground (GND)	6	DSR (in)	5	GND
6	Data Set Ready (DSR in)	7	GND	6	DSR (in)
7	Data Terminal Ready (DTR out) (tied to 4)	8	DCD (in)	7	RTS (out)
8	No Connection	20	DTR (out)	8	CTS (in)
9	No Connection	22	Ring in (in)	9	Ring in (in)

Figure 8-6. SERIAL I/O (DTE) Connector Details

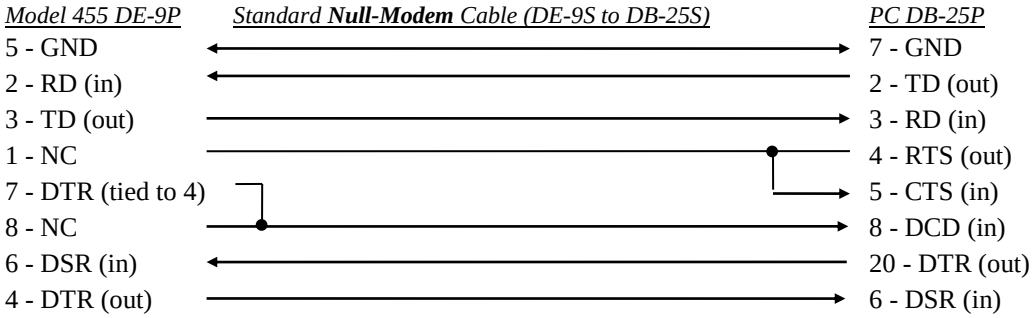
8.10.1 Serial Interface Cable Wiring

The following are suggested cable wiring diagrams for connecting the Model 455 Serial Interface to various Customer Personal Computers (PCs).

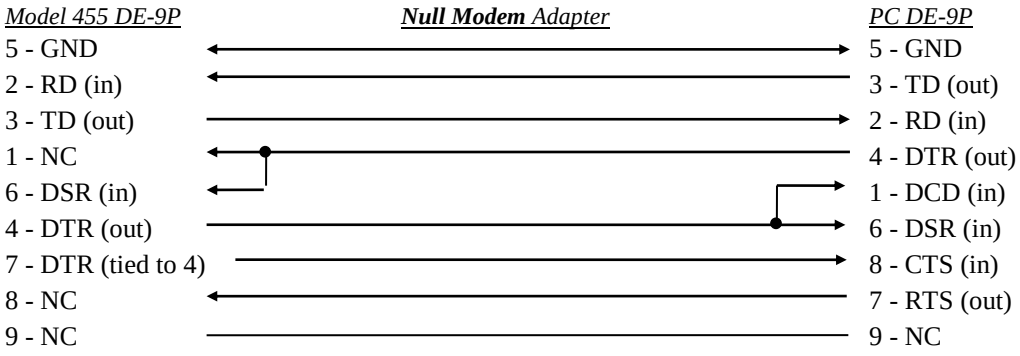
Model 455 to PC Serial Interface – PC with DE-9P



Model 455 to PC Serial Interface – PC with DB-25P



Model 455 to PC Interface using Null Modem Adapter

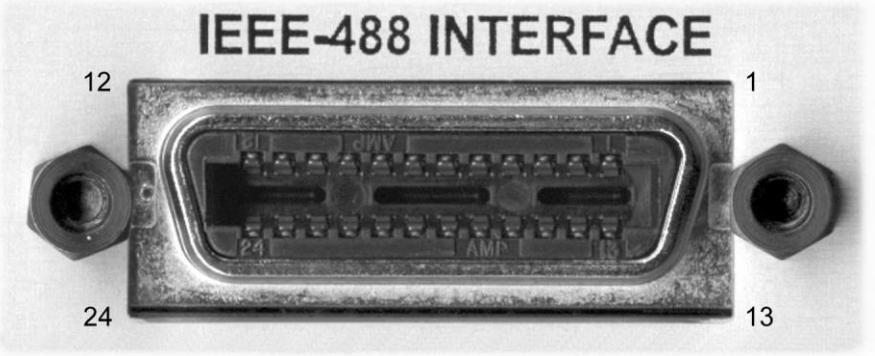


NOTE: Same as null modem cable design except PC CTS is provided from the Model 455 on DTR.

8.10.2 IEEE-488 INTERFACE Connector

Connect to the IEEE-488 Interface connector on the Model 455 rear with cables specified in the IEEE-488-1978 standard document. The cable has 24 conductors with an outer shield. The connectors are 24-way Amphenol 57 Series (or equivalent) with piggyback receptacles to allow daisy-chaining in multiple device systems. The connectors are secured in the receptacles by two captive locking screws with metric threads.

The total length of cable allowed in a system is 2 meters for each device on the bus, or 20 meters maximum. The Model 455 can drive a bus of up to 10 devices. A connector extender is required to use the IEEE-488 Interface and the Auxiliary I/O connector at the same time. Figure 8-7 shows the IEEE-488 Interface connector pin location and signal names as viewed from the Model 455 rear panel.



IEEE_Connector.bmp

PIN	SYMBOL	DESCRIPTION
1	DIO 1	Data Input/Output Line 1
2	DIO 2	Data Input/Output Line 2
3	DIO 3	Data Input/Output Line 3
4	DIO 4	Data Input/Output Line 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable Shield
13	DIO 5	Data Input/Output Line 5
14	DIO 6	Data Input/Output Line 6
15	DIO 7	Data Input/Output Line 7
16	DIO 8	Data Input/Output Line 8
17	REN	Remote Enable
18	GND 6	Ground Wire – Twisted pair with DAV
19	GND 7	Ground Wire – Twisted pair with NRFD
20	GND 8	Ground Wire – Twisted pair with NDAC
21	GND 9	Ground Wire – Twisted pair with IFC
22	GND 10	Ground Wire – Twisted pair with SRQ
23	GND 11	Ground Wire – Twisted pair with ATN
24	GND	Logic Ground

Figure 8-7. IEEE-488 INTERFACE Connector Details

8.11 CALIBRATION PROCEDURE

8.11.1 Equipment Required for Calibration

PC and Interface

- PC with software loaded which provides serial command line communication. (Example program in Section 6.2.7 is ideal for this purpose.)
- DE-9 to DE-9 cable. Pin to pin connections on all 9 pins. Female connectors on both ends.
- DE-9 null modem adapter.

Test and Measurement Equipment

- Digital Voltmeter (DVM). Voltage and current specs to be equivalent to or better than HP3458 specs.
- Function Generator. Frequency and voltage specs to be equivalent to or better than HP/Agilent 33120 specs.
- One 332 Ω, 0.1%, 25 ppm resistor.
- One 33.2 Ω, 0.1%, 25 ppm resistor.
- One 3 Ω, 0.02%, 4-lead resistor (Precision Resistor Corporation, PLV 3 or equivalent).
- One 300 mΩ, 0.02%, 4-lead resistor (Precision Resistor Corporation, PLV½ or equivalent).
- One 30 mΩ, 0.05%, 4-lead resistor (Precision Resistor Corporation, PLV½ or equivalent).
- One 4.3 mΩ, 0.25%, 4-lead resistor, created by placing a 30 mΩ and a 5 mΩ resistor in parallel (Precision Resistor Corporation, PLV½ or equivalent).
- One 2 kΩ, 0.1%, 25 ppm resistor.
- One 22.1 kΩ, 0.1%, 25 ppm resistor.
- One 200 kΩ, 0.1%, 25 ppm resistor.

8.11.2 Gaussmeter Calibration

The Model 455 is calibrated against a set of standard resistors. The Model 455 is configured to give readings in ohms. The highest range for the 100 mA excitation current is calibrated by measuring the 3 Ω standard resistor. This resistor is measured by using the HP 3458 to measure the current source of the Model 455 and the voltage across the resistor. This configuration is only valid for this range because the accuracy of the HP3458 is unacceptable for the remaining Model 455 ranges. Therefore, the remaining ranges are calibrated by using the previous calibrated range as shown in the following steps.

8.11.2.1 Gaussmeter Calibration, 100 mA Excitation Ranges

1. Set the Gain Correction Factor to 1 for all five of the 100 mA hall current source ranges (CALG 1,1,1;CALG 1,2,1…).
2. Connect a short across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
3. Configure the Model 455 for 100 mA excitation current (HALLCS 1).
4. Configure the Model 455 for DC 5 digits (RDGMODE 1,3,1,1,1) on the 3.5 Ω range (RANGE 5).
5. Zero the probe using the Zero Probe key or the ZPROBE command.
6. Connect the 3 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
7. Configure the Model 455 for 100 mA excitation current (HALLCS 1).
8. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
9. Verify the measurement to be 3.00000 Ω, ±10%.
10. Connect the DVM current input in series with the hall current source generated by the Model 455 to measure the current through the 3 Ω resistor.
11. Configure the Model 455 excitation current to +100 mA (HALLCS 1;CSMODE 2).
12. Read the current using the DVM. Store as AVGPOSCURRENT.
13. Connect the DVM voltage input across the 3 Ω resistor.
14. Read the voltage using the DVM. Store as AVGPOSVOLTAGE.
15. Connect the DVM current input in series with the hall current source generated by the Model 455 to measure the current through the 3 Ω resistor.

16. Configure the Model 455 excitation current to -100 mA (HALLCS 1;CSMODE 3).
17. Read the current using the DVM. Store as AVGNEGCURRENT.
18. Connect the DVM voltage input across the 3 Ω resistor.
19. Read the voltage using the DVM. Store as AVGNEGVOLTAGE.
20. Calculate EXPECTEDRESISTANCE = (AVGPOSVOLTAGE - AVGNEGVOLTAGE) / (AVGPOSCURRENT - AVGNEGCURRENT).
21. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE/ ACTUALRESISTANCE. Test this factor to be 1.0, ±2%.
22. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 1,5,<GCF>).
23. Connect the 3 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
24. Configure Model 455 for 100 mA excitation current (HALLCS 1), normal excitation current mode (CSMODE 1).
25. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.01%.
26. Connect the 300 mΩ resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
27. Configure the Model 455 for 100 mA excitation current (HALLCS 1).
28. Read the resistor using the Model 455 (RDGOHM?). Store as EXPECTEDRESISTANCE.
29. Configure the Model 455 range to the 350 mΩ range (RANGE 4).
30. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
31. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE /ACTUALRESISTANCE. Test this factor to be 1.0, ±2%.
32. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 1,4,<GCF>).
33. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.01%.
34. Repeat steps 26 thru 33 for the 35 mΩ and 3.5 mΩ ranges (range 3 and 2) using the 30 mΩ and 4.3 mΩ resistors respectively.
35. Send the Gain Calibration Factor (GCF) calculated for range 2 to range 1. The hardware gains for those two ranges are equivalent.
36. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.2.2 Gaussmeter Calibration, 10 mA Excitation Ranges

This section describes the method of calibrating the 10 mA current source that may be used for future Hall sensors. The five ranges of the Model 455 will need to be calibrated for each current setting. The highest range is for each current is calibrated using a 33.2 Ω resistor that is measured using the 3458 in a four lead resistance measurement mode. The remaining ranges are calibrated by using the previous calibrated range as shown in the following steps.

1. Set the Gain Correction Factor to 1 for all five of the 10 mA hall current source ranges (CALG 2,1,1;CALG 2,2,1…).
2. Connect the 33.2 Ω resistor to the DVM using a proper 4-lead connection.
3. Read the resistor using the DVM. Store as EXPECTEDRESISTANCE.
4. Connect a short across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
5. Configure the Model 455 for 10 mA excitation current (HALLCS 2).
6. Configure the Model 455 for DC 5 digits (RDGMODE 1,3,1,1,1) on the 35 Ω range (RANGE 5).
7. Zero the probe using the Zero Probe key or the ZPROBE command.
8. Connect the 33.2 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
9. Configure the Model 455 for 10 mA excitation current (HALLCS 2).
10. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
11. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE/ACTUALRESISTANCE. Test this factor to be 1.0, ±3%.
12. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 2,5,<GCF>).
13. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.02%.
14. Connect the 3 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
15. Configure the Model 455for 10 mA excitation current (HALLCS 2).
16. Read the resistor using the Model 455 (RDGOHM?). Store as EXPECTEDRESISTANCE.

17. Configure the Model 455 range to the 3.5 Ω range (RANGE 4).
18. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
19. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE /ACTUALRESISTANCE. Test this factor to be 1.0, ±2%.
20. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 2,4,<GCF>).
21. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.02%.
22. Repeat steps 14 to 21 for the 350 mΩ and 35 mΩ ranges (range 3 and 2) using the 300 mΩ and 30 mΩ resistors respectively.
23. Send the Gain Calibration Factor (GCF) calculated for range 2 to range 1. The hardware gains for those two ranges are equivalent.
24. Configure the Model 455 to use the 100 mA excitation current (HALLCS 1).
25. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.2.3 Gaussmeter Calibration, 1mA Excitation Ranges

This section describes the method of calibrating the 1 mA current source that may be used for future Hall sensors. The five ranges of the Model 455 will need to be calibrated for each current setting. The highest range is for each current is calibrated using a 332 Ω resistor that is measured using the 3458 in a four lead resistance measurement mode. The remaining ranges are calibrated by using the previous calibrated range as shown in the following steps.

1. Set the Gain Correction Factor to 1 for all five of the 1 mA hall current source ranges (CALG 3,1,1;CALG 3,2,1…).
2. Connect the 332 Ω resistor to the DVM using a proper 4-lead connection.
3. Read the resistor using the DVM. Store as EXPECTEDRESISTANCE.
4. Connect a short across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
5. Configure the Model 455 for 1 mA excitation current (HALLCS 3).
6. Configure the Model 455 for DC 5 digits (RDGMODE 1,3,1,1,1) on the 350 Ω range (RANGE 5).
7. Zero the probe using the Zero Probe key or the ZPROBE command.
8. Connect the 332 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
9. Configure the Model 455for 1 mA excitation current (HALLCS 3).
10. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
11. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE/ACTUALRESISTANCE. Test this factor to be 1.0, ±3%.
12. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 3,5,<GCF>).
13. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.02%.
14. Connect the 33.2 Ω resistor across the Gaussmeter input of the Model 455 using a proper 4-lead connection.
15. Configure the Model 455 for 1 mA excitation current (HALLCS 3).
16. Read the resistor using the Model 455 (RDGOHM?). Store as EXPECTEDRESISTANCE.
17. Configure the Model 455 range to the 35 Ω range (RANGE 4).
18. Read the resistor using the Model 455 (RDGOHM?). Store as ACTUALRESISTANCE.
19. Calculate the Gain Calibration Factor (GCF) = EXPECTEDRESISTANCE /ACTUALRESISTANCE. Test this factor to be 1.0, ±2%.
20. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 3,4,<GCF>).
21. Read the resistor using the Model 455 (RDGOHM?). Verify the reading to be EXPECTEDRESISTANCE ±0.02%.
22. Repeat steps 14 to 21 for the 3.5 Ω and 350 mΩ ranges (range 3 and 2) using the 3 Ω and 300 mΩ resistors respectively.
23. Send the Gain Calibration Factor (GCF) calculated for range 2 to range 1. The hardware gains for those two ranges are equivalent.
24. Configure the Model 455 to use the 100 mA excitation current (HALLCS 1).
25. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.3 Temperature Measurement Calibration

This section performs the calibration on the temperature measurement. The Model 455 has three excitation currents for temperature measurement. Each one of these is used to measure the appropriate 0.1% resistor. Calibration constants and offsets are calculated and sent to the Model 455.

1. Set the Temperature Gain Correction Factor to 1 and the Offset Correction Factor to 0. (CALG 5,3,1;CALZ 5,3,0)
2. Connect the 2 kΩ resistor to the DVM using a proper 4-lead connection.
3. Read the resistor using the DVM. Store as TEMPDESIRED.
4. Connect a short across the temperature input of the Model 455 using a proper 4-lead connection.
5. Configure temperature current source for 1mA amplitude, manual mode (CALTEMP 1,3)
6. Read the resistor using the Model 455 (RDGTRES?). Store as TEMPOHMOFFSET.
7. Send the Offset Calibration Factor (OCF) to the Model 455 (CALZ 5,3,TEMPOHMOFFSET).
8. Connect the 2 kΩ resistor across the temperature input of the Model 455 using a proper 4-lead connection.
9. Read the resistor using the Model 455 (RDGTRES?) Store as TEMPACTUAL.
10. Calculate the Gain Calibration Factor (GCF) as TEMPDESIRED/TEMPACTUAL. Test this factor to be 1.0, ±2%
11. Send the Gain Calibration Factor (GCF) to the Model 455 (CALG 5,3,<GCF>)
12. Read the resistor using the Model 455 (RDGTRES?). Verify the reading to be TEMPDESIRED, ±0.05%.
13. Repeat steps 1 thru 12 for the remaining two current excitations using the following table guidelines.

Current	*Command*	*Nominal Resistance*	*Expected Cal Constant*	*Verify Reading*
1 mA	CALTEMP 1,3	2 kΩ	1.00 ±2%	DVM Measure ±0.05%
100 uA	CALTEMP 1,2	22.1 kΩ	1.00 ±2%	DVM Measure ±0.05%
10 uA	CALTEMP 1,1	200 kΩ	1.00 ±2%	DVM Measure ±0.05%

14. Configure the Model 455 for temperature autoranging (CALTEMP 0,3).
15. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.4 Analog Output 2 and 3 Calibration

This section will perform the actual calibration of Analog Output 2 and 3. This involves reading the positive and negative full-scale output voltages of each output, calculating correction constants for gain and offset of each output and writing them back to appropriate calibration locations in the Model 455. These values are to be used whenever the outputs are accessed. The gain and offset values should also be checked to assure that they are reasonable in value and reject them if they fall outside a given range. Analog Output 2 uses slightly different full-scale range since it is a ±5 volt output that will never exceed ±3.5 volts in normal operation.

8.11.4.1 Analog Output 2 Calibration

1. Set Analog Output 2 Gain Correction Factor to 1 (CALG 4,2,1) and Offset Correction Factor to 0 (CALZ 4,2,0).
2. Connect the DVM to Analog Output 2.
3. Configure Analog Output 2 to manual mode, -90% (MOUT 1,-90).
4. Read the voltage using the DVM. Record as VMIN.
5. Configure Analog Output 2 to manual mode, +90% (MOUT 1,90).
6. Read the voltage using the DVM. Record as VMAX.
7. Calculate the Gain Correction Factor (GCF) = 9 / (VMAX – VMIN). Note: Gain is calculated over the full span of the output. Test this factor to be 1.0, ±1%. Record this value.
8. Send the Gain Correction Factor (GCF) to the Model 455 (CALG, 4,2,<GCF>).
9. Configure Analog Output 2 to manual mode, 0% (MOUT 1,0).
10. Read the voltage using the DVM. Record as VZERO.
11. Calculate the Offset Correction Factor (OCF) = -(VZERO) * (100% / 5). Note: The offset voltage is expressed as a percentage of Full Scale. Test this factor to be between -1 and 1. Record this value.
12. Send the Offset Correction Factor (OCF) to the Model 455 (CALZ 4,2,<OCF>).

13. Configure Analog Output 2 to manual mode, -50% (MOUT 1,-50).
14. Read the voltage using the DVM. Verify the reading to be –2.5 VDC, ±1 mV. Record the reading.
15. Configure Analog Output 2 to manual mode, +50% (MOUT 1,50).
16. Read the voltage using the DVM. Verify the reading to be +2.5 VDC, ±1 mV. Record the reading.
17. Configure Analog Output 2 to manual mode, 0% (MOUT 1,0).
18. Read the voltage using the DVM. Verify the reading to be 0 VDC, ±1 mV. Record the reading.
19. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.4.1 Analog Output 3 Calibration

1. Set Analog Output 3 Gain Correction Factor to 1 (CALG 4,3,1) and Offset Correction Factor to 0 (CALZ 4,3,0).
2. Connect the DVM to Analog Output 3.
3. Configure Analog Output 3 to manual mode, -100% (ANALOG 3,2,0,0,-100,10).
4. Read the voltage using the DVM. Record as VMIN.
5. Configure Analog Output 3 to manual mode, +100% (ANALOG 3,2,0,0,100,10).
6. Read the voltage using the DVM. Record as VMAX.
7. Calculate the Gain Correction Factor (GCF) = 20 / (VMAX – VMIN). Note: Gain is calculated over the full span of the output. Test this factor to be 1.0, ±1%. Record this value.
8. Send the Gain Correction Factor (GCF) to the Model 455 (CALG, 4,3,<GCF>).
9. Configure Analog Output 3 to manual mode, 0% (ANALOG 3,2,0,0,0,10).
10. Read the voltage using the DVM. Record as VZERO.
11. Calculate the Offset Correction Factor (OCF) = -(VZERO) * (100% / 10). Note: The offset voltage is expressed as a percentage of Full Scale. Test this factor to be between -1 and 1. Record this value.
12. Send the Offset Correction Factor (OCF) to the Model 455 (CALZ 4,3,<OCF>).
13. Configure Analog Output 3 to manual mode, -100% (ANALOG 3,2,0,0,-100,10).
14. Read the voltage using the DVM. Verify the reading to be –10 VDC, ±1 mV. Record the reading.
15. Configure Analog Output 3 to manual mode, +100% (ANALOG 3,2,0,0,100,10).
16. Read the voltage using the DVM. Verify the reading to be +10 VDC, ±1 mV. Record the reading.
17. Configure Analog Output 3 to manual mode, 0% (ANALOG 3,2,0,0,0,10).
18. Read the voltage using the DVM. Verify the reading to be 0 VDC, ±1 mV. Record the reading.
19. Send the CALSAVE command to save the calibration constants into non-volatile memory.

8.11.5 Calibration Specific Interface Commands

CALG Gain Calibration Constant Command

Input: **`CALG <type>, <range>, <value>[term]`**

Format: n,n,±nnnnnnn

<type> Specifies the item to calibrate. Valid entries are:
1 = 100 mA hall current source
2 = 10 mA hall current source
3 = 1 mA hall current source
4 = Analog Outputs (1-3)
5 = Temperature

<range> Specifies the range of the item to calibrate. Valid entries are:
1 = 300 μΩ range (hall current source), 10 μA range (temperature), Analog Output 1 (not used)
2 = 3 mΩ range (hall current source), 100 μA range (temperature), Analog Output 2
3 = 30 mΩ range (hall current source), 1 mA range (temperature), Analog Output 3
4 = 300 mΩ range (hall current source)
5 = 3 Ω range (hall current source)

<value> Gain calibration constant value.

Remarks: Some entries are not calibrated and are indicated by "not used." No value should be sent to these locations.

CALG? Gain Calibration Constant Query

Input: **`CALG? <type>,<range> [term]`**

Format: n,n

<type> 1–5

<range> 1–5

Returned: <value>[term]

Format: ±nnnnnnn (Refer to command for description)

CALSAVE Calibration Save Command

Input: **`CALSAVE [term]`**

Remarks: Saves all CALZ and CALG calibration constants in non-volatile memory.

CALTEMP Temperature Measurement Setup Command

Input: **`CALTEMP <mode>, <range>[term]`**

Format: n,n

<mode> Specifies the operating mode of the temperature measurement. Valid entries are:
0 = Normal mode, autorange on
1 = Manual range mode

<range> Specifies the current source range of the temperature measurement. Valid entries are:
1 = 10 μA range (250 kΩ range)
2 = 100 μA range (25 kΩ range)
3 = 1 mA range (2.5 kΩ range)

Remarks: This command is used to set the temperature measurement to manual mode so that each range can be calibrated. Default is mode = 0 (autorange).

CALTEMP? Temperature Measurement Setup Query

Input: **`CALTEMP? [term]`**

Returned: <mode>, <range>[term]

Format: n,n (Refer to command for description)

CALZ

Zero Offset Calibration Constant Command

Input: **`CALZ <type>, <range>, <value>[term]`**

Format: n,n,±nnnnnnn

<type> Specifies the item to calibrate. Valid entries are:
- 1 = 100 mA hall current source (not used)
- 2 = 10 mA hall current source (not used)
- 3 = 1 mA hall current source (not used)
- 4 = Analog Outputs (1-3)
- 5 = Temperature

<range> Specifies the range of the item to calibrate. Valid entries are:
- 1 = 300 μΩ range (hall current source, not used), 10 μA range (temp.), Analog Output 1 (not used)
- 2 = 3 mΩ range (hall current source, not used), 100 μA range (temp.), Analog Output 2
- 3 = 30 mΩ range (hall current source, not used), 1 mA range (temp.), Analog Output 3
- 4 = 300 mΩ range (hall current source, not used)
- 5 = 3 Ω range (hall current source, not used)

<value> Zero offset calibration constant value.

Remarks: The range variable is ignored but needs to be sent for types that do not need to specify a range (types 2, 3, and 4). A range value of 1 should be sent for those types. The hall current sources do not have a calibrated zero. The offset is corrected using the Zero Probe function.

CALZ?

Zero Offset Calibration Constant Query

Input: **`CALZ? <type>, <range>[term]`**

Format: n,n

<input> 1 – 5

<type> 1 – 5

Returned: <value>[term]

Format: ±nnnnnnn (Refer to command for description)

CSMODE

Configure Hall Current Source Mode Command

Input: **`CSMODE <mode> [term]`**

Format: n

<mode> Specifies the hall current source mode. Valid entries are:
- 0 = Current off
- 1 = Normal mode (current reversal)
- 2 = Positive current
- 3 = Negative current

Remarks: Configures the hall current source mode. The current output (100 mA, 10 mA, or 1mA) is dependent on range (see HALLCS).

CSMODE?

Configure Hall Current Source Mode Query

Input: **`CSMODE? [term]`**

Returned: <mode>[term]

Format: n (Refer to command for description)

HALLCS Hall Current Source Range Command

Input: **`HALLCS <range>[term]`**
Format: n
<range> Specifies the hall current source range. Valid entries are:
1 = 100 mA range
2 = 10 mA range
3 = 1 mA range
Remarks: If a new probe is connected or the power is cycled on the instrument, the hall current source will default back to the lowest current range, range 3 (1 mA). If an invalid probe is attached to the instrument, sending the HALLCS command will clear out the "Invalid Probe" message and the instrument will begin reading in ohms.

HALLCS? Hall Current Source Range Query

Input: **`HALLCS? [term]`**
Returned: <range>[term]
Format: n (Refer to command for description)

KEYST? Last Key Press Query

Input: **`KEYST?[term]`**
Returned: <code>[term]
Format: nn (Refer to command for description)

00 = no key pressed since last query	08 = "Enter"	16 = "6"
01 = "+/-"	09 = "Relative"	17 = "7"
02 = "Up"	10 = "Reset"	18 = "8"
03 = "Escape"	11 = "1"	19 = "9"
04 = "Max Hold"	12 = "2"	20 = "0"
05 = "Peak"	13 = "3"	21 = "DC"
06 = "."	14 = "4"	22 = "RMS"
07 = "Down"	15 = "5"	99 = multiple keys pressed simultaneously

MOUT Analog Output 2 Setup Command

Input: **`MOUT <mode>, <setting>[term]`**
Format: n, ±nnnnnnn
<mode> Specifies the operating mode Analog Output 2. Valid entries are:
0 = Normal mode, output follows reading
1 = Manual setting mode
<setting> Analog Output 2 manual setting value, ±100%.
Remarks: This command is used to set Analog Output 2 to a manual setting value so that the output can be calibrated. Default is mode = 0 (normal).

MOUT? Analog Output 2 Setup Query

Input: **`MOUT? [term]`**
Returned: <mode>, <setting>[term]
Format: n, ±nnnnnnn (Refer to command for description)

RDGTRES? Temperature Sensor Resistance Reading Query

Input: **`RDGTRES? [term]`**
Returned: <thermistor resistance>[term]
Format: ±nnnnnnn

APPENDIX A

UNITS FOR MAGNETIC PROPERTIES

Table A-1. Conversion from CGS to SI Units

Quantity	Symbol	Gaussian & CGS emu[a]	Conversion Factor, C[b]	SI & Rationalized mks[c]
Magnetic flux density, Magnetic induction	B	gauss (G)[d]	10^{-4}	tesla (T), Wb/m^2
Magnetic Flux	ϕ	maxwell (Mx), $G \cdot cm^2$	10^{-8}	weber (Wb), volt second (V·s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization[g]	M	emu/cm^3[h]	10^3	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2[i]
(Mass) magnetization	σ, M	emu/g	1 $4\pi \times 10^{-7}$	$A \cdot m^2/kg$ $Wb \cdot m/kg$
Magnetic moment	m	emu, erg/G	10^{-3}	$A \cdot m^2$, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	$Wb \cdot m$[i]
(Volume) susceptibility	χ, κ	dimensionless emu/cm^3	— $(4\pi)^2 \times 10^{-7}$	Henry per meter (H/m), Wb/(A·m)
(Mass) susceptibility	χ_ρ, κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$ $(4\pi)2 \times 10^{-10}$	m^3/kg $H \cdot m^2/kg$
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$ $(4\pi)^2 \times 10^{-13}$	m^3/mol $H \cdot m^2/mol$
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A·m)
Relative permeability[j]	μ_r	not defined	—	dimensionless
(Volume) energy density, energy product[k]	W	erg/cm^3	10^{-1}	J/m^3
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

NOTES:

a. Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.

b. Multiply a number in Gaussian units by C to convert it to SI (e.g. $1\ G \times 10^{-4} T/G = 10^{-4} T$).

c. SI (Système International d'Unités) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where to $\mu_0 = 4\pi \times 10^{-7} H/m$. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.

d. 1 gauss = 10^5 gamma (γ).

e. Both oersted and gauss are expressed as $cm^{-½}\ g^{½} \cdot s^{-1}$ in terms of base units.

f. A/m was often expressed as "ampere-turn per meter" when used for magnetic field strength.

g. Magnetic moment per unit volume.

h. The designation "emu" is not a unit.

i. Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.

j. $\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ.

k. B H and $\mu_0 M$ H have SI units J/m^3, M H and B H/4π have Gaussian units erg/cm^3.

R.B. Goldfarb and F.R. Fickett, U.S. Department of Commerce, National Bureau of Standards, Bolder, Colorado 80303, March 1985, NBS Special Publication 696. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table A-2. Recommended SI Values for Physical Constants

Quantity	Symbol	Value (SI units)
Permeability of Vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Speed of Light in Vacuum	c	2.9979×10^{8} m s^{-1}
Permitivity of Vacuum	$\varepsilon_0 = (\mu_0 c^2)^{-1}$	8.8542×10^{-12} F m^{-1}
Fine Structure Constant, μ0ce2/2h	α α^{-1}	0.0073 137.0360
Elementary Charge	e	1.6022×10^{-19} C
Plank's Constant	h $h = h/2\pi$	6.6262×10^{-34} J Hz^{-1} 1.0546×10^{-34} J s
Avogadro's Constant	N_A	6.0220×10^{23} mol^{-1}
Atomic Mass Unit	1 u = 10^{-3} kg mol^{-1}/N_A	1.6605×10^{-27} kg
Electron Rest Mass	m_e	0.9109×10^{-30} kg 5.4858×10^{-4} u
Proton Rest Mass	m_p	1.6726×10^{-27} kg 1.0073 u
Neutron Rest Mass	m_n	1.6749×10^{-27} kg 1.0087 u
Magnetic Flux Quantum	$\phi = h/2e$ h/e	2.0679×10^{-15} Wb 4.1357×10^{-15} J Hz^{-1} C^{-1}
Josephson Frequency-Voltage Ratio	2e/h	483.5939 THz V^{-1}
Quantum of Circulation	$h/2m_e$ h/m_e	3.6369×10^{-4} J Hz^{-1} kg^{-1} 7.2739×10^{-4} J Hz^{-1} C^{-1}
Rydberg Constant	R_∞	1.0974×10^{7} m^{-1}
Proton Moment in Nuclear Magnetons	μ_p/μ_N	2.7928
Bohr Magneton	$\mu_B = eh/2m_e$	9.2741×10^{-24} J T^{-1}
Proton Gyromagnetic Ratio	γ_p	2.6752×10^{8} s^{-1} T^{-1}
Diamagnetic Shielding Factor, Spherical H_2O Sample	$1 + \sigma(H_2O)$	1.0000
Molar Mass Constant	R	8.3144 J mol^{-1} K^{-1}
Molar Volume, Ideal Gas (T_0 = 273.15K, p_0 = 1 atm)	$V_m = RT_0/p_0$	0,0224 m^3 mol^{-1}
Boltzman Constant	$k = R/N_A$	1.3807×10^{-23} J K^{-1}
Stefan-Boltzman Constant	$\sigma = (\pi^2/60)\, k^4/h^3\, c^2$	5.6703×10^{-8} W m^{-2} K^{-4}
First Radiation Constant	$c_1 = 2\pi hc^2$	3.7418×10^{-16} W m^{-2}
Second Radiation Constant	$c_2 = hc/k$	0.0144 mK
Gravitation Constant	G	6.6720×10^{-11} N m^2 kg^{-2}

Data (abbreviated to 4 decimal places) from CODATA Bulletin No. 11, ICSU CODATA Central Office, 19 Westendstrasse, 6 Frankfurt/Main, Germany. Copies of this bulletin are available from this office.